PUMPS

AND

PUMPING MACHINERY.

PUMPS

AND

PUMPING MACHINERY.

BY

FREDERICK COLYER, M. INST. C.E., M. INST. M.E.,
CIVIL ENGINEER.

Pt. 1

LONDON:
E. & F. N. SPON, 16, CHARING CROSS.
NEW YORK:
44, MURRAY STREET.
1882.

PREFACE.

THE favourable manner in which my book on Hydraulic and Steam Lifting Machinery has been received, has led me to write another treatise upon a subject of equal interest to the Profession. The object of the present work is the same as the last, not to discuss very rudimentary matters, but to afford practical information to Civil Engineers, Architects, and others, to assist those who require it and are specifying for such kind of work.

It is hoped that the examples given, especially the data of working results, will prove of value to those who are seeking such information. All tables and other data may be relied upon; facts only are stated, and no theories entered into. I have adopted the same plan as before, in writing this work in a short terse style, for the purpose of offering only practical matter in as few words as possible, having found this generally most acceptable to those who want information given in a small compass.

Most of the work described is from my personal experience, except those matters specially stated.

I have, in conclusion, to offer my sincere acknowledgments to several firms for their kindness and courtesy in furnishing me with particulars and drawings of their respective kinds of work.

In offering the book to my professional brethren, I must ask their kind indulgence for all shortcomings, and hope it may meet with as kind a reception as my former literary efforts.

FREDERICK COLYER, M. INST. C.E., M. INST. M.E.,
Civil Engineer.

18, GREAT GEORGE STREET, WESTMINSTER, S.W.
June 1882.

CONTENTS

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

LIST OF DRAWINGS.

PUMPS AND PUMPING MACHINERY.

CHAPTER I.

INTRODUCTION.

THE author does not think it necessary to enter into a history as to the first use of the ordinary pump, lift and force pumps of the usual type for domestic supply are now so well known that no notice need be taken of them. Descriptions of machinery at work, derived in most cases (except in some specially mentioned) from his own practice and experience are given. He would like it to be understood, where any data are given, especially as to the performance of machinery of any kind, that they may be taken in all cases as good average results, and not mere experiments. Dimensions are given of the leading apparatus connected with pumping machinery and plant, as well as various types of engines and boilers, to indicate to those who have not had much experience in this class of work what they should specify in stating their wants. The author hopes it may prevent in future, to some extent, the issue of the crude specifications and drawings that are too often seen, especially as they place contractors who tender for the work in an unfair position. Where so much is left to their own ideas, it necessarily follows that the tenders are very wide as to price. In the present day, when the lowest tender is usually accepted, it is necessary to have all the details of a proposed work clearly defined, especially as to the leading dimensions and way of finishing the work.

The subjects treated are pumps of various kinds, for water and other purposes, engines, boilers, and general machinery connected with pumping and water supply. In the class of

steam and other special kinds of pumps, only those that have stood the test of good work, and that have come within the author's practice, are noticed; there are, unfortunately, many in the market which give very poor results. In these cases it would be useless to describe what could not be recommended confidently for use.

Several engines, pumps, &c., of a large class are described in detail, to give an idea of the dimensions of good types of work, which the author trusts will be of much service to some in determining the requisite proportions for kindred works. All dimensions and particulars of this kind are from actual examples of good work, and can be relied on for accuracy.

In treating of water pumping for the supply of towns, the distribution of the water beyond the works is entered into but slightly, as this is not within the scope of the book, and also because such matters have been fully treated by others who have written upon the subject.

Air pumps for various purposes are described in detail, both for exhausting, and for charging vessels with air under pressure. Blowing engines for steel and iron works are also treated, and examples given and data of working results.

Lift Pumps.

For pumping water from wells to the surface of the ground, or for raising water into elevated tanks, &c., for ordinary purposes, pumps of this class are usually employed. For raising water for factory and other purposes, single pumps may be used in some cases where the quantity of water is not large, and where a continuous flow is not a matter of much importance. In instances of this kind the pumps may be fixed to a cast-iron plate on the wall of a building, and worked by an eccentric or crank from any convenient shaft. The details of the pump barrels, valves, &c., do not much differ from the three-throw pumps next described, full particulars of which are given.

Three-throw Pumps are the most efficient for raising water in any quantity from the surface, or from a depth not exceeding 25 feet below the suction valves; they are fixed between A frames, and worked by a three-throw crank or eccentrics; they give a continuous flow of water, work efficiently, with very little wear and tear, and being free from complications

are not liable to get out of order. The following is a description of a set of 6-inch diameter by 18-inch stroke pumps (see Drawing No. 1) of this class, suitable for raising water under a "head" of say 60 feet to 70 feet above the pump barrels; if for a greater lift, all parts of the pumps must be made stronger, the air vessels larger, and sundry other alterations in the details. Anything beyond this depth comes into deep-well pumping, which will be noticed hereafter (see p. 9).

PUMPS, 6 inches diameter by 18 inches stroke.—The barrels are 6 inches internal diameter, and are usually made with a stroke equal to $2\frac{1}{2}$ to 3 times the diameter, and of gun-metal, $\frac{5}{8}$ inch thick, with flanges at top and bottom, $\frac{3}{4}$ inch thick, turned on the faces. A valve box of cast iron at top and bottom, divided into chambers for each pump, is fitted with valves and seats of gun-metal; the area of these should be about $\frac{1}{3}$ the area of the pump; ample area should be given round the valves, to prevent undue friction in the water passing. At each valve and seat, hand-holes for the examination of the valves are provided; they should have faced covers, and be secured by two bolts or studs. The valves should be made to rise upon a fixed pin, the seat being held in its place by a cross bar; the lift is regulated by the depth of the top of valve. For water, the valves may be gun-metal, with flat or conical face, or a disc of gun-metal, with indiarubber or leather fastened to same; each valve and seat should be capable of examination, removal, adjustment, and re-starting in less than 10 to 15 minutes.

The suction and delivery pipes may be equal in area to the diameter of one pump barrel. The barrels are attached to the valve boxes, named above, by means of flanges, secured by bolts and nuts. The pump buckets are of gun-metal, and packed with gasket, with valves of the same material, and made like the suction and delivery valves before described.

The bucket rods are of copper or steel, $1\frac{1}{8}$ inch diameter, and are keyed to wrought-iron or steel cross heads, having steel rods keyed at the upper ends, which work through the cast-iron guide bars bushed with gun-metal, attached to the side A frames.

THE A FRAMES, in which the pumps are set, are of cast iron, made I section, well spread out at the feet; these are carried on a base plate; the facings are planed. The upper part of the frames are stayed with cast-iron stretchers, having

bolts passing through the centre. At the top of the frames plummer blocks are fixed to take the crank shaft. In some cases the frames are fixed to a cast-iron bed plate, in others the feet are bolted direct to the stone bed.

THE CRANK SHAFT to work the pumps, should be of wrought iron or steel, and three-throw, the pins being the same size as the bearings, 3½ inches diameter by 3½ inches wide. Clarke's patent bent cranks make a good job, are economical, and strong; it is advisable to have them shaped and got up bright to detect any defects, they should be made of scrap iron.

The connecting rods are of wrought iron, and have gun-metal heads at the crank-pin end and forked ends, with gun-metal or strapped ends at the cross heads; the diameter of the rods in the smallest part should not be less than 1¼ inch, and each side of the forks of equal area to same.

The guides for the pump rods are gun-metal bushes, fitted to cast-iron cross bars, attached to one set of the stretchers before named. The bushes are 2¼ inches deep, and have a cupped recess at the top to receive the oil; they are bored to receive the rods, and turned on the outside, the cross bars being bored out to receive them, the bushes are driven into these holes and riveted to secure them.

The plummer-block bearings for the crank shaft should be 3½ inches diameter by 4½ inches wide, faced at the base, and bolted to the top of the side frames, which are also faced at this part to receive them; the holes are drilled and bolts turned; this prevents movement, and takes off any strain. Wrought-iron keys are fitted at each end of the blocks, bearing against "joggles" cast on the top of the frames; this keeps them rigid; two steady pins should also be fitted to each of the plummer blocks, these pins should be at least ¾ inch diameter, and perfectly fit the holes drilled in the frames.

The suction pipes will not in practice draw from a greater depth than about 25 to 26 feet vertical below the suction valves, but the horizontal distance, provided the joints are tight, does not affect the question. It is advisable to have a catch valve in the vertical pipe, and one or more in the horizontal pipe, according to the length of the suction pipes. A rose should be fixed on the bottom of the pipe, to prevent grit and dirt getting into the pumps. The pipes may either be

copper or cast-iron faced flange pipes, in say 6 to 9 feet lengths, bolted together, or where the pumps are small, they may be of wrought iron, either screwed together by sockets, or flanged, screwed on, and bolted together.

The delivery pipe should have an air vessel of copper or cast iron, fixed on or close to the top valve box, say 12 inches diameter by 3 feet 6 inches to 4 feet high; this, if made of copper, should be 5 to 5½ lbs. per superficial foot, and have a gun-metal flange brazed on the bottom ¾ inch thick; a draw-off cock must be fitted at the bottom of the air vessel. It is a good plan to have an air vessel on the suction also, especially where the pumps are some distance from the well, &c.

Driving Gear.—Straps are the most suitable, working on to "fast" and "loose" pulleys; the width of the strap for pumps of this size should be 4½ to 5 inches. The pulleys should be turned on the face and coned to give a good grip to the strap; the size of the pulleys on the crank shaft should not be less than 20 inches diameter by 6 inches wide.

Tooth-wheel gear.—When these are used the pinion should have iron teeth, pitched and trimmed, and the wheel geared with wood cogs. The pinion should have a clutch cast on, to allow it to be thrown out of gear when required. No fixed rules can be given as to the diameter and number of teeth, as it will vary according to the size of the pumps, their speed, and the "head" of water to be pumped.

Number and Diameter of Pumps.

It is not usually advisable to have more than three pumps in one set, or the size to exceed 7 to 8 inches diameter by 24 inches stroke, extra sets being provided to give the power required for the particular case. The advantage of this arrangement is that, in the event of a break-down, spare sets are available to carry on the work, and do not cause a complete stoppage of the pumping operations. This important fact should always be remembered.

When pumping on a large scale and for special purposes, a battery of pumps of ten or twelve may be fixed in a pump house; in this case they may be attached to cast-iron girders, which are built into the walls of the room at each end. The

pumps have separate valve boxes, suction and delivery pipes, or the valve boxes top and bottom may be arranged in sets of three and four pumps each.

They are worked by one over-head shaft carried on brackets, &c., having eccentrics keyed on for each pump. The guides for the pump rods are the same as before described. To throw the pumps out of gear the cross heads slide on the steel pump rods when the keys are disengaged. In a case of this description, the shaft should be driven by a separate engine and by strap gear, and a duplicate engine provided in case of a break-down; and where there are more than six pumps, the top shaft should be divided in the centre and fitted with clutch gear, to throw in and out as desired. The object of this arrangement is to allow part of the gear only to work if a portion of the pumps are out of action, thus saving unnecessary wear.

Eccentrics do not cause any more friction than cranks, but care must be taken that the shafts are strong, say in the above case not less than 3½ inches diameter at the smallest part for 6- and 7-inch diameter pumps. Bearings must be provided at every three pumps to keep the shaft rigid; loose collars should be fitted at each side. The straps of the eccentrics should be wide and the connecting rods stiff where the lift is heavy, and should be braced from the sides of the straps at the bolts.

Large lubricators should be fitted to each eccentric, and care taken to see that they are well charged with oil to ensure free lubrication; the top half of the strap must be channelled to allow free passage for the oil.

Speed of Pumps.—It is always advisable to work pumps at a slow speed. For 3 and 4 inches diameter, 30 strokes; 5 and 6 inches, 20 strokes; and 7 and 8 inches, 16 to 18 strokes per minute. Very little is gained by over-driving pumps, as the "slip" through the valves is much increased, and the wear and tear also, owing to the heavy shocks to which they are subjected at the closing of the valves.

Pumps for Special Work.

Beer Pumps.—The barrels should always be made of gun-metal, the valve boxes may be of same material for small pumps, and for large sizes of cast iron; the buckets and valves of gun-metal. In some cases canvas valves are used; they

are not, however, to be recommended, as they are apt to foul, and are always difficult to keep clean, which is a most important consideration in pumps of this class. Indiarubber or leather for the valves or the buckets should never be used.

For an ordinary brewery, 4, 5, and 6 inches diameter pumps are the best sizes, and the stroke about three times the diameter. One duplicate set should always be kept for use in case of any break-down; it is advisable to work all the pumps at regular intervals to ensure their being in proper working order when wanted.

The speed should not exceed, for pumps 4 inches say 25 strokes, 5 inches 20 strokes, and 6 inches 18 strokes per minute.

The general details of the pumps in other respects are the same as described at pp. 3 to 5. Most parts of the pumps and gear should be got up bright in order to keep them clean more easily, and save labour.

TAR AND AMMONIACAL LIQUOR PUMPS FOR GASWORKS.—The barrels, valves, and valve boxes should all be made of cast iron; the pump rods of steel or wrought iron.

All joints should be faced and holes drilled; the valves must have free area and rather small lift. Each pump as a rule is fitted with a separate suction and delivery valve box, and with separate pipes, to use singly in case of a break-down of any one of the pumps. The suction and delivery pipes should be equal to about ½ diameter of the pump, bends should be avoided whenever possible, and elbows should never be used.

AIR VESSELS should be cast iron of ample capacity, and provided with draw-off cock at the base; balloon-shaped vessels act the best, and retain the air longer than when made parallel in diameter. The delivery pipe should be at the bottom of the air vessel, dip pipes at the top are not so good, they take out too much of the contents of the air vessels.

The valve chambers must have ample area, and the bonnets to the valves should be large, to enable the *valve and seat* to be removed and replaced rapidly in case of any obstruction causing a stoppage. The bonnets should be attached by two or four bolts according to the size of the pump, or studs may be used; in all cases the bonnets and seats must be faced and the holes drilled, with steady pins, to ensure the bonnets being

fixed in the proper place each time the joint is broken and re-made.

In large pumps where the rods are liable to get cut, wrought-iron rods may be cased with cast iron; they stand the wear well, as there is little or no chemical action upon cast iron from tar or any of its constituents; the wrought-iron rods must be turned rather rough, and after the cast iron is run on they should be left in the sand to anneal for several hours to prevent any sudden contraction, the surface of the cast-iron casing is then turned and polished.

These pumps in small places are used single, fixed to a cast-iron plate attached to the wall, and worked by wheel, gear, or straps. The speed should be slow, to allow the valves to close at the end of each stroke.

Messrs. George Waller and Co., of Southwark, have been very successful in the manufacture of this class of pump. It may be remarked that tar pumps should always be free from complication. The author does not recommend the use of double-acting pumps for this purpose, the valve arrangements are too complicated, and are liable to get out of order and cause a stoppage to the pumps.

Vinegar Pumps are made much the same as the ordinary lift pumps, except that the barrels are sometimes made of glass or vulcanite; they stand very well, and give very little trouble. In old times the barrels used to be made of wood, and were worked by long poles and "rockers" to each pump. These poles reached in some cases 100, 200, and 300 feet. Although very cumbersome, they did the work very well, but the cost of repairs was always heavy. Pumps for this purpose are usually used as single pumps, to pump the vinegar into the various separate vessels. The details of the pumps are much the same as for ordinary lift pumps in other respects.

Sewage Pumps.—Where lift pumps are used, they should be made of cast iron with leather buckets, and valves of same material. The area through the valve seats and the valve boxes should be ample, and means of getting at all parts of the pumps should be carefully considered. The general details of the pumps in other respects do not differ from those before described. In many cases force pumps are used with both open

and closed tops. The most suitable valves are of leather, and of the clack kind, weighted on top with gun-metal or wrought-iron plates.

Well Pumps (Drawing No. 2).—The details of the pumps as to the method of construction are much the same as described on p. 3 to 4. The valves, however, differ according to the size of the pumps and the "head" of water to be pumped. This will be more fully treated hereafter.

The pump barrels must be made of sufficient thickness to take the pressure according to the "head" of water under which they are worked, and, instead of being connected by flanges to the top and bottom valve boxes, they are checked into recesses in the boxes, and secured by long bolts, which pass through the top and bottom boxes, and so hold them firmly together. The valve boxes must be extra strong, varying in thickness according to the "head" of water pumped. The lower valve box should not be more than 10 to 15 feet from the surface of the water.

Where the well is deep and the water rises above the barrels, they should be extended to the surface by bolting on sufficient pipes, and the upper valve box fixed near the top of well, with the stuffing boxes and glands placed convenient for packing. Each of these pipe barrels forms its own rising main, and has its own separate chamber and valve.

The suction valves and the seats, which are of gun-metal and conical in shape, are of less diameter outside than the bore of the barrels; the seats have a bridge cast on, and are drawn to the surface by means of a chain and hook when it is necessary to make an examination. In this case they work in separate boxes.

Air Vessels should be fixed on the lower valve box, and where there is not room in the well a separate chamber can be constructed in the side walls for same. They can be made of cast iron or wrought iron, should be of ample size, and provided with a cock to drain the rising main and admit air at certain periods; gear to control this cock must be carried to the top of the well. The air in an air vessel after a short time becomes absorbed by the water, and if not occasionally re-charged, it becomes useless; in some cases small air pumps are used at the surface to force air through pipes carried down the well to the

air vessel. A large air vessel should also be fixed at the top of well; this should be wrought iron for large pumps; and on the delivery main should be a safety valve to take off any shock in case of stoppage anywhere in the pipes.

The air vessels at top, when of wrought iron, should be made $\frac{5}{16}$ to $\frac{3}{8}$ inch thick, according to the pressure, and with double riveted joints, the edges of the plates planed and all holes drilled. When there is sufficient room they should stand upon the floor of the engine house. Draw-off cocks and air cocks, also water gauge and pressure gauge should be provided.

Valves for Deep Wells.—The best pump valves are those made upon the Cornish plan, double beat, all gun-metal, as named hereafter. Valves for lifts of more than 50 feet for small pumps should be of the spindle kind, or made to rise on a fixed centre pin. Flat faces for metal valves are as a rule better than conical faces, more especially where the water is gritty. "Wing valves" should never be used; they often give trouble by sticking. The valves for well pumps, especially when for deep lifts, should have free area, as well as all the passages and pipes. No sharp angles should be allowed anywhere, and all bends should be easy. "Tee" connections should enter the main pipes by easy curves, and not at a sharp angle as generally made. Square or round "elbows" should never be used; when there are any unavoidable sharp bends, air cocks should be provided and fixed *on the bend* to let out the air and ensure perfect circulation of the water.

For small-size pumps and low lifts, where the water is very sandy or gritty, "clack valves" may be used in some cases with advantage. These can either be made of gun-metal or leather backed with gun-metal; the leather must be thick, oil dressed, of the best quality, and carefully faced.

Where these valves are used for large pumps, a small valve is fitted on the top of the large valve, to take off the shock, on account of the smaller area: this closes and opens first, and so relieves the pumps. These act very well, are very simple, and not liable to get out of order.

Cornish Valves are made of gun-metal, with "double beats," and have hard wood faces, or gutta-percha working on gun-metal *flat* faces. The bucket valve is made in the same way. The suction valves usually have three or four beats.

There are several modifications of this valve, with two, three,

and four beats or faces; but although they are somewhat cheaper in first cost, the author does not recommend their use, as many are very complicated, apt to stick, are noisy in working, cause much vibration in the machinery, and consequent extra friction.

For deep pumping, with pumps say from 6 inches diameter and above, the "Cornish" are the most efficient valves, and as they last a long period without getting out of order, will be found the cheapest in the end.

Indiarubber Valves can be used for light lifts and pumps of small diameter. They should always be made to rise on a fixed centre-pin, secured to a top plate of gun-metal, and have a bush of the same material at the centre. In some cases thick leather may be used in lieu of indiarubber, plated in the same way as before described. Indiarubber valves should not be used to turn up against an iron guard, as they wear at the centre part where they are held down, and fail in a short time; when indiarubber valves were first introduced they were made on this plan, but they never have acted so well as when made on the first named system.

A plan has been tried with two, three, and four separate discs of indiarubber, with holes in same, placed one above the other; they do not always act very well, and for deep lifts should never be used. The red rubber in all cases stands the best, and should not be less than ½ inch thick; the thickness will vary with the size of the pump and valves. The grids on which the valves work should always be faced, and the holes carefully proportioned to the size of the valves; they may either be made of cast iron or gun-metal, the latter are the best.

The Pump Bucket Rods should either be made of copper or steel—the author prefers the latter. The connecting pump rods, for deep wells, can be of wood bound with iron, or they may be wrought-iron rods or tubes connected together with gun-metal sockets. The wood rods answer well, are both light and rigid, and last for many years.

Girders with guide rollers attached should be fixed at every 7 or 8 feet from the top of delivery valve box to the top of well, except where the barrels are carried up to the top of the well as before described, when they are not required.

Top Driving Gear.—The crank shaft should have three

throws and be made of steel or wrought iron; steel is the best, and the extra cost not large, they are cut out of the solid, the pins must be the same diameter as the bearings. The plummer blocks should have gun-metal bearings not less than 2 diameters in length. The ends of the connecting rods should be solid gun-metal attached to T-heads forged on the wrought-iron rods; the fork ends should be made either with solid gun-metal ends, or may have strap or fork ends fitted with bearings, and adjusted with gibs and keys.

The crank shaft should be driven by tooth gear from a shaft having a pinion with iron teeth pitched and trimmed, and a clutch to throw out when required; the wheel on the crank shaft should be a mortice wheel (the width of the teeth should be rather less than the pinion).

Eccentrics may be used in lieu of cranks for small pumps (say to 5 or 6 inches diameter barrels), and when the lifts are low; in this case the shaft should be not less than 4 to 4½ inches diameter, and fitted with a centre bearing, this prevents it from springing and saves vibration of the rods and gear, and consequent extra wear.

The straps of the eccentrics should be wide, and either made of gun-metal or lined with same. The width of the bosses should equal 1¼ diameters of the shaft, and be fitted with wrought-iron hoops shrunk on each side to strengthen them. The keys must have sunk beds and very little taper; for large sizes two keys should be used. In all cases the keys must be very carefully fitted.

There is an advantage in using eccentrics; if a break-down in the gear takes place they can be more rapidly repaired than when cranks are used. In several cases in the author's experience he has put in new gear in four days after the fracture, when ten days at least would have been the shortest time to replace a crank-shaft, even of small size.

The eccentric rods should be braced; when this is done the rods may be made of less diameter, and will be more rigid than single rods. Check nuts should be fitted to the bolts at the lugs of the eccentrics, and the keys to the rods cross-pinned when made with a socket; it is, however, preferable to make them with a T-head fixed to the strap by two bolts, which should be turned and fit in drilled holes.

Girders for Fixing Pumps in Wells should be cast iron,

rest on stone templates, firmly built in the wall at least 12 to 14 inches on either side, and run in Portland cement. Many serious fractures may be traced to the careless way of fixing sometimes employed by unskilful workmen, especially in deep wells and where much supervision cannot be given. Where the well is in chalk or soft stone, and not lined with brickwork or stonework, the part where the pump girders rest must be cut out, and sufficient brickwork or masonry put in to ensure a perfectly solid bed, and prevent any crumbling of the materials, which would be caused by the strain of the pumps, especially when working under heavy "heads."

All faces on the girders should be planed and the bolt holes drilled. When the pumps are large and the valve boxes heavy, two extra girders must be fixed for the lower valve box to rest on, built in as before described. In some cases it is advisable to connect these two sets of girders with iron framing, to increase the rigidity and spread the strain over a double base; the stone templates should not be less than 12 inches thick, and at least 12 to 18 inches wide by 18 inches long.

Stages of wood or iron should be fixed in the wells at each 10 or 11 feet, and iron well ladders provided, to allow of easy and rapid access to the rods and valve boxes in case of any stoppage. Cast-iron open-grated stages, supported on wrought-iron girders, are the most suitable, and in the end prove the most economical; at the level of suction valve box of the pumps a stage should be carried across the well, filling up the space between the pumps, a trap-door being left to give access to the suction pipe. This plan prevents accident, in case of any of the men slipping they cannot fall into the water; every possible precaution should be taken to avoid accidents.

Position of the Pumps in the Well.—Provision should be made for fixing duplicate pumps, and to allow of this, each set of pumps is fixed near the side of the well, with separate rising mains, and top driving gear; arrangements must be made to use either one or two sets of pumps, should necessity require. In the case of water supply to a town or public establishment, provision should always be made to meet a sudden emergency.

Lift Pumps are used for various other purposes, with barrels made of glass, pewter, lead, and other materials. They

do not, however, much differ from those previously described, except in minor details, which are too minute and would take up too much space to describe here.

The speed of lift pumps depends upon the liquid to be pumped. They always perform better duty when driven at a low speed, as it allows the valves to close before another stroke is taken, so avoiding slip.

Quality of Pumps.—Until late years lift pumps of moderate size were made in a very indifferent way, by "pump makers"; engineers did not care to make them, owing to the unfair position they were placed in as to price, on account of the inferior quality of the workmanship and materials of many makers. The use of inferior pumps is very false economy, as the bad results they give in working, and consequent loss, much more than counterbalance the extra first cost of a really good and well-made apparatus. The author feels he cannot too fully recommend all designers and users of pumps to have the best class only, and by an extra outlay at first to avoid trouble in the subsequent working.

Wells.

For ordinary water supply a few remarks are here given on wells, merely as a guide, as the subject is extensive, and beyond the scope of this book.

When the water to be pumped is for domestic use or manufacturing purposes, unless chalk or hard rock is passed through at or near the surface, the sides are usually lined with cast-iron cylinders, sunk as the well is dug. These cylinders have internal flanges, bolted together in about 6-feet to 7-feet lengths; the diameter of the cylinders depends upon the size of the pumps, and varies from 3 feet to 8 or 9 feet internal diameter; they are carried down a sufficient depth to shut out the surface water. The depth of the top well depends upon the height the water rises, and the quantity required; after about 100 to 200 feet, if water is not met with of the requisite quantity and quality, a bore hole is sunk and pipes driven. Six-inch diameter pipes are the smallest size to give a supply of any moment; the size of the tubes depends upon the depth to be bored. Where there is little surface water and the strata passed through are solid, the top well may be lined with brickwork set in

Portland cement, or the lining may be made in Portland cement concrete; this, however, must be executed with the greatest care by skilled men, and with the best materials. In this case a drum of wood, equal in diameter to the internal size of the well, is used, and the concrete filled in at the back; the details, however, cannot be entered into here. Any one wishing further information, is referred to the author's book on 'Breweries and Maltings' (Spon).*

The above remarks as to wells are given merely as an outline of what is usually required; the construction nearly always depends upon special circumstances; it is advisable to have professional assistance from those experienced in such matters, otherwise a large amount of money may be lost. It must be remembered well-boring is a costly operation, and there is much uncertainty of finding water even in a district where there are other wells yielding a good supply; this is on account of the "faults" met with in the strata. A small test bore-hole is usually sunk first to ascertain the strata to be passed through and the probability of finding water; if water is not found another one is sunk.

Steam Lift Pumps.

In large places, where water, beer, or other liquids have to be pumped from a lower to an upper vessel, a battery of pumps, say six or eight, may be set in a cast-iron frame and entablature, worked by a pair of steam cylinders fixed in the centre between the two sets or on the outside of the frames. The valve boxes of each set may either be connected, with one rising main to each set, or separate valve boxes and mains fitted to each, so as to pump separate liquors, &c., to various apparatus situated at different parts; this is a very good arrangement, and where the shafting is at some distance it is very economical in working. The length of the steam pipe from the boilers is not of much moment, provided it is well clothed and protected, to save condensation. The advantage of this kind of pump is, they can be started at any time, entirely independent of the rest of the machinery, thus saving the wear and tear of long lengths of shafting, also the risk of stoppage from fracture, straps slipping, and other causes.

* 'Breweries and Maltings; their Arrangement, Construction, Machinery, and Plant.' E. & F. N. Spon.

The steam cylinders are connected by spur and tooth gear to the crank shafts of the pumps, and are worked at a slow speed, not exceeding 18 to 20 strokes per minute for 6 inch and 7 inch pumps. The framing and machinery must have a solid foundation in brickwork, and be secured to same by bolts, 3 feet to 3 feet 6 inches long, with large plates and collars. The base plate of the pump should rest upon a "York" bed-stone, not less than 9 inches to 12 inches thick; all the work should be done in Portland cement. The brickwork should rest upon concrete of a thickness varying according to the kind of bottom foundation; but in all cases it should be at least 12 inches wider on all sides than the footing of the brickwork, to ensure a good base. Much expense is saved in the repairs of the pumps, &c., by having a solid foundation. There are various forms of these self-contained pumps, but the details do not much differ from that described above.

CHAPTER II.

FORCE PUMPS.

Plunger Pumps for Water.—These are made with cast-iron or gun-metal bodies, and the plungers of gun-metal, the valves and seats of the same materials. The plungers are cast hollow and when from 3 to 4 inches diameter should be $\frac{1}{2}$ to $\frac{9}{16}$ inch thick.

The valves are fitted in a box or chamber, one on either side of the barrel, a bonnet or cover is provided at each valve to allow of examination and adjustment when necessary. The best kind of valves are the spindle kind, the seats being fitted into bored recesses; at the bonnets set screws should be fitted to regulate the lift of valves. The area through the valves should be about one-fourth the area of plungers, the annular space in the chamber round the valves should be rather more to avoid friction.

The connecting rods are wrought iron, and attached to the plunger by steel pins; the width of the eyes of the rods should be at least double the diameter of the pin, and in large pumps should be fitted with brasses capable of adjustment as wear takes place, by setting up a key. When the distance from the driving shaft to the top of plungers is small the rods may be attached to the bottom of the plunger, which is left open for this purpose; it gives a longer connecting rod, and acts as a better guide for the plunger in the barrel.

Pet-cocks should be fitted both at the suction and delivery boxes to discharge the air and ensure the perfect action of the pumps at each stroke.

The pumps can either be set in a frame three in each set, or arranged as described at p. 6, and worked by top shaft and eccentrics. The rods should have bored sockets and keys to

allow any of the pumps to be disengaged without stopping the rest. Each pump has separate suction and delivery pipes.

Safety Valves should be provided at the delivery mains to take off the shock in case of any undue pressure, the accidental closing of a valve, or any stoppage in the pipes.

When this class of pumps are used for sugar liquor they must be made entirely of gun-metal, the valves in this case should have rather larger area than when used for water, and the sizes of the suction and delivery pipes increased; this saves friction, which is rather heavy when pumping this kind of fluid. Air vessels of ample size should always be provided on the delivery main.

Well Pumps (Force) are made upon this plan, especially where a single pump only can be used; they are generally made double acting, all the valves being gun-metal, and either clack or spindle kind before described, or on the Cornish plan.

For deep well pumping upon this plan see separate description, pp. 75–81.

Hydraulic Press Pumps.

These pumps are usually made of gun-metal, with the chambers and valve boxes of same material; for small places, where one or two presses only have to be supplied, two or more 1-inch diameter and two or more 2-inch diameter pumps are set in a tank of water and worked by hand levers or by shafting and gear; for full description of these pumps see the author's book on 'Hydraulic Lifting and Pressing Machinery.'* These pumps being of a very special character, hardly come under the head of ordinary water pumping. It is sufficient here to say the work must be of the highest class, and made very strong. The pipes should be of thick copper, or may be Perkin's patent hydraulic pipes. The pressure to be borne is from 2 to 5 tons per square inch. The pumps are worked by hand or steam power, either by steam cylinder direct or from adjoining shafting.

Steam Force Pumps (Vertical).

A set of three, six, or more pumps are set in a frame and worked by two steam cylinders, one fixed on each side of the

* 'Hydraulic, Steam, and Hand-power Lifting and Pressing Machinery.' London: E. & F. N. Spon.

frame. The steam cylinders have the usual connecting rods working on to one crank shaft, connected by spur-wheel gear to the pump shaft; the rods have bored sockets, as before described, to disengage by drawing out the keys, when required to stop the pumps. The suction and delivery pipes are either made separate to each pump or one to each set of three; the area of the pipes must in all cases exceed the area of the valves, to save friction. All sharp bends must be avoided, this is a most essential matter with this kind of pumps.

There are many purposes to which pumps of this kind can be applied, viz.:—Feeding a line of boilers, pumping for hydraulic press work, or hydraulic lifts, creosoting apparatus, &c.

The speed should not exceed 30 to 40 strokes per minute for 3 inch to 4 inch diameter plungers. Air vessels of ample capacity should always be provided with the fittings previously described; these vessels may either be made of copper or of cast iron. Safety valves must be provided on the pipes near the air vessels; the levers of the valves should be well fitted and graduated for the weights. The foundations for the pumps should be made as described at p. 16. The depth of the brickwork will, however, depend upon the head or pressure on the pumps, their size, the nature of the ground, and other circumstances.

Steam Donkey Pumps (Direct Acting).

There are many forms of these; the author considers the "Model" pump made by Messrs. Thornewill and Warham, and Tonkin's patent pumps are the best of their particular class, either of which can be worked at a slow speed and can be started easily. As a rule steam pumps worked by "tappets" are not economical as to steam used, and are apt to stick and give trouble; those made with crank-shaft fly-wheels, and with eccentrics for working the slides, are free from the above objections, and are very economical as to the steam used. One great advantage with independent direct-acting pumps is, that being self-contained and the driving power forming part of the machine, they can be fixed anywhere without any regard to the distance from the boiler, they can be started at any time, and when no pumping is required the machinery stands, and no wear and tear takes place. They are in some cases fixed a

short distance down a well, the steam being carried down through a pipe covered with composition, passing through another large pipe to protect it.

TONKIN'S PATENT "CORNISH" STEAM PUMP (Drawing No. 3).

Tonkin's patent direct-acting steam pump consists of a steam and pump cylinder, placed in a line with each other and connected by a distance piece fitted with the usual stuffing boxes, the end flanges form the covers for both cylinders; the steam piston, which is of the usual form and size, is fixed on the same piston rod as the pump bucket. The pump is double-acting, and fitted with the ordinary pump valves. The special feature of this steam pump, however, is the means adopted for reversing the main slide valve by *steam alone*, without the intervention of any crank shaft, eccentric, tappets, levers, or other mechanical motion.

The steam cylinder is provided with the usual steam passages and exhaust port, opening out on the slide valve facing as usual; but these cylinder ports, together with the steam chest, are arranged at the side of the cylinder, and kept low enough down to enable all condensed water to at once drain out of the cylinder through the exhaust port. The slide valve is of the engine form, but it is moved to and fro by a long cast-iron piston, having projections cast on it, which are fitted over the back of the slide valve, thus allowing it always to work steam-tight on the cylinder face notwithstanding wear.

This slide-valve piston moves to and fro in the bored ends of the steam chest, which have covers bolted on, thus forming small cylinders at each end. This slide-valve piston is also bored out, and the ends closed by caps screwed in steam-tight; inside this slides a plain cast-iron piston valve, not connected to the slide valve, but provided with a port towards each end to enable it to admit or exhaust steam from the ends of the slide-valve piston as required. These ports are so arranged as to be always in communication with the respective outside ends of the slide-valve piston, through side passages in the same; and they are, by the movement of the inside piston valve, alternately put into communication either with one of the steam holes or the exhaust slots in the outside slide-valve piston, thereby admitting steam to one end of it

and exhausting the steam at the same time from the other end through the side passages, in such a manner as to cause the outside valve piston (carrying the slide valve with it) to follow the movement of the inside piston valve. The steam holes in the slide-valve piston open direct to the steam space in the steam chest; the exhaust slots are in communication with ports cast in the bottom of the steam chest, which are led across and past each other into the main cylinder passages at the opposite ends, these passages being of course open alternately to the exhaust pipe through the slide valve.

In order to give motion to this inside piston at the completion of the stroke of the main piston, the ends of the valve are, by the previous movement of the outside slide-valve piston, put in communication alternately, through a hole at either end, with small ports in the top of the steam chest and leading down to near each end of the main cylinder. When the main piston arrives at the end of its stroke in either direction, it uncovers one of these small ports, and the steam behind it passes up this port and through the hole in the outside slide-valve piston to act on one end of the inside piston valve, and move it over; the opposite end of this inside valve being then open to the exhaust slot in the bottom of the slide-valve piston, through a small hole which is then uncovered, the exhaust steam passing from this slot through one of the bottom ports in the steam chest into the cylinder passage, which is then open to the exhaust owing to the position of the slide valve. This movement of the inside piston valve will be immediately followed by that of the outside slide-valve piston (as previously described) in the same direction, carrying the slide valve with it and so reversing the flow of steam in the main cylinder.

Both the slide-valve piston and the inside piston valve are cushioned on steam at the end of their strokes by passing over and closing their respective exhaust ports, the edge of the inside piston valve closing over its small exhaust hole, and the end of the exhaust slot in the slide-valve piston passing over and closing the exhaust port in the bottom of the steam chest at either end. The main piston is also cushioned in a similar manner, the cylinder passages entering the cylinder a short distance from each end, so that the piston, when near the end of its stroke, passes over and closes them, and so cushions itself on the imprisoned steam. Thus the momentum of the main and

valve pistons are checked, and striking the cylinder and steam chest covers is effectually prevented. This small inside piston valve, and the slide-valve piston with its slide valve, are the only *two moving parts* in the valve gear. An outside handle is provided for moving the steam valves at any time when desired, this handle being connected with a finger inside the steam chest engaging in a slot in the valve pistons, but with sufficient clearance at the ends to allow the handle to remain stationary during ordinary working, as the valve pistons do not move far enough to touch the inside finger.

From the above description it will be seen that the operation of moving the slide valve is very simple, and the arrangement has the following special advantages:—

1st.—Great economy in first cost, and absence of liability to injury arising either from external violence or from stoppage or loss of water in the pump; the delivery pipe may be suddenly closed or air admitted to the suction without any damage whatever occurring.

2nd.—Greater durability from the absence of tappets, or any mechanical contacts between the piston and the steam valves; and also from the efficient cushioning of all the moving parts.

3rd.—Greater certainty of action at all speeds, however slow, as the two valve pistons have the steam acting on them for the whole of their stroke, instead of depending on their momentum to help them over the centre, as in the case of a single valve piston.

4th.—Compactness: the steam cylinder and its piston being of the usual length in proportion to its stroke.

One of these pumps is at work in a colliery in the north of England pumping water through 700 feet of piping, with 450 feet perpendicular height, in one lift, with a steam pressure of 40 lbs. per square inch. The steam cylinder is 26 inches diameter, and the pump 8½ inches diameter, both of them having 4 feet stroke.

A direct-acting steam pump, working at a colliery, used during a fortnight: 5·8 cwt. of *unscreened* coal per hour in pumping about 9000 gallons per hour to a height of 1000 feet, or at the rate of 14·4 lbs. of *unscreened* coal per hour per *actual* horse-power of water lifted (about 8 lbs. per indicated horse-power). The friction of pipes, &c., would, however, add considerably to the actual work on the engine. This is equivalent

to 63·8 cwt. of unscreened coal, to lift 1,000,000 gallons 100 feet high. It may be noted that unscreened coal was used direct from the pit. If good steam coal had been used the result would have been better.

THE "MODEL" STEAM PUMP (Drawing No. 4).

This steam pump is made by Messrs. Thornewill and Warham, of Burton-on-Trent; it is horizontal, self-contained, and on one bed plate; it can be easily fixed. A 10-inch steam cylinder size, has a pump 5 inches diameter and 12 inches stroke, and will raise 7500 gallons per hour, say 50 feet high. The suction pipe is 3½ inches diameter, and the delivery 3 inches. The pump is placed between the steam cylinder and fly-wheel shaft, the slide of the steam cylinder is worked by a small crank off the crank shaft; it is double-acting, and furnished with a large air vessel on the delivery and suction pipes. The pumps can be worked from a few strokes per minute to 70 or 80 per minute; they give a steady and regular delivery, work silently, and without vibration. As the details of the engine portion do not much differ from the usual horizontal type of steam engine, further detail of this portion is not necessary.

The pump is perfect of its kind, and any stoppage from a break-down seldom or never occurs; the small sizes are very useful apparatus for feeding steam boilers, and the larger sizes can be used for water supply, stationary fire-engines, and many other purposes. When applied in breweries for pumping hot "wort," special valves are provided. For pumping tar at gas-works, the valves and other parts have to be of cast iron and specially constructed. The pressure of steam required to work them is from 15 lbs. per square inch to 40 lbs., according to the quantity to be pumped and height to be raised.

The author has used them largely in breweries to raise water from wells (the water not exceeding 26 feet deep below the surface), to the cold water tank on top of the building, usually 50 feet to 60 feet above the ground line. The great advantage is in this case, they can be set to work at any time convenient without starting any other part of the machinery. The cost of pumping as to fuel, &c., is the same as with ordinary pumps, and the risk of fracture is much less.

Portable Steam Pumps.

Pumps with engine and boiler fixed on one frame are most efficient apparatus for temporary pumping, such as for keeping excavations clear of water, emptying reservoirs, and for temporary water supply to towns, &c., in case of a break-down of the ordinary fixed engines and pumps. Engine and pumps combined of this class are manufactured by Messrs. George Waller & Co., of Southwark, and have been successfully applied by the firm to the above and kindred purposes for the last thirty-five to forty years.

The boiler is fixed upon a frame of wrought iron, mounted on wheels, the two front ones are made to swivel in the same way as an ordinary carriage. The engine is fixed direct on top of the boiler; the steam cylinder in some cases forms part of the steam chest, by this method very little condensation takes place; the piston rod is keyed to a cross head carrying the guide blocks, working a side guide-bar of steel, or two bars in the centre and one guide block. A wrought-iron connecting rod works direct on the wrought-iron crank, working in bearings fitted in cast-iron side frames, also bolted to the top of the boiler or fixed on the lower frame. On the end of the crank shaft on one side is a wrought-iron pinion working into a spur wheel on the crank shaft of the pump.

The pumps are three in number, fixed on the main iron frame, which is prolonged for this purpose, and carries the boiler and engine; the valve boxes are made separate, with large bonnets to each valve, for the purpose of examining same. The valves are sometimes of indiarubber, leather, or gun-metal; the buckets are made solid, and packed with double leathers or gasket; metallic rings have been used, they do not, however, wear so well, especially where the water is sandy or gritty.

These pumps are most efficient in action and can be set to work within two hours or less of their arrival on the spot. In several cases within the author's experience, these pumping engines have been sent 70 and 80 miles out of London, and have been set to work within ten hours from the time when the order was given to send them off from the firm's works.

No other portable pumping apparatus can compete with them as to the quantity discharged, economy in working, and the rapid way in which they can be set to work. The value of

such machinery in case of emergency need hardly be further dwelt upon, experience having proved their efficiency.

The boilers are "multitubular" on the locomotive plan, with a fire box, the shell of boiler is felted or covered with composition and lagged with wood to prevent loss of heat. The whole complete machine can be drawn by horses direct to the spot where required. Shafts are attached at the fire-box end, which are unshipped when not in use; the smoke funnel is hinged, and extra length added when at work as required. The blast pipe passes into the funnel to increase the draught of furnace. The boiler is fed by a force pump worked off the cross head of the engine, or any injector may be used. The quantity of water that can be pumped by these engines is:—

No. 1.—Three	7 inch	diameter	pumps,	10,000	galls.	per	hour.
No. 2.— „	9 „	„	„	20,000	„	„	
No. 3.— „	12 „	„	„	40,000	„	„	

drawing the water from 25 feet below the pump valves, and discharging into a trough about the same level as delivery valve chamber. They can also pump from greater depths by removing the pumps from the engine frame and lowering them in the well, and can raise the water under "heads" of 60 feet and above; of course, in this case, the quantity discharged is less than named above.

As no straps are employed there is no risk of stoppage on account of fracture, and there being three pumps, if one breaks down either one or two can be worked alone. The author employed one of these engines, a few years ago, to fill a gasholder tank by pumping from a river situated about a mile away; the engine was placed upon the bank of the river, and a temporary pipe with bored joints laid to carry the water to the tank. Allowing for all expenses, about 90*l.* to 100*l.* was saved, viz. the difference between the cost of hire and all expenses incurred in pumping, and the amount asked by the water company to fill the tank.

The cost would have been less had the pipes been larger in diameter, as only two out of the three pumps could be worked at one time and at a slow speed, owing to the small area of the delivery main.

Steam Pumps (Horizontal).

Another form of pump which can be worked as a single pump, is constructed thus: a steam cylinder is fixed to a cast-iron bed plate horizontally, with guides, connecting rod, crank shaft, and fly wheel; the pump is fixed on the same plate, either at the front or back of the cylinder; they are usually made double acting, and with metal or indiarubber valves; the suction or delivery pipes should be made free, and the valves accessible. It is very advantageous to use air vessels of good capacity, both on the suction and delivery pipes. The sizes of the water and steam cylinders are arranged to suit the quantity to be pumped per hour and "head" of water; allowance must be made where there are many *unavoidable* bends in the pipe. Steam pressure should not be less than 45 to 50 lbs. per square inch.

The pump barrels are usually made of cast iron, and in some instances are lined with gun-metal. As a rule, steel rods wear the best, working through gun-metal glands and collar bushes. The speed varies with the size of the pump; a 6-inch or 7-inch diameter may be worked up to 50 and 60 strokes per minute; the valves have small lift given to them. It is however, usual to employ pumps of a much larger size, say 10-inch to 12-inch and 14-inch diameter, when this system of pumping is adopted.

The foundation should be of brickwork in cement, with a good York stone base, not less than 9 inches to 12 inches thick, the holding bolts and plates being taken down at least 3 feet 6 inches to 4 feet into the brickwork, which should rest upon a bed of concrete.

Steam Fire Engines.

There are two kinds of steam fire engines made in England, both direct acting, having the steam- and water-cylinders rigidly connected. In one of these systems the stroke of the piston is regulated by the admission of steam near the end of the stroke, which forms a "cushion." In the other kind the work is done by a crank and connecting rod, with eccentric for working the slide valve, as in the engines made by Messrs. Shand, Mason, and Co., for the Metropolitan Fire Brigade.

In these latter engines the boilers are of Bowling iron, the longitudinal seams being welded, a large number of small water tubes are placed in an inclined position to allow of free circulation, one steam and one water cylinder are fixed vertically on the boiler, and at the back of the carriage.

The pumps are double acting, of the bucket and plunger kind. The engines are direct acting; a crank is used to terminate the stroke, the slide valves being worked by eccentrics in the usual way. The pumps are made of gun-metal, with air vessels of copper upon the delivery and suction pipes. All the steam and exhaust pipes are copper. A feed pump is used to supply the boiler, and a Giffard injector is also attached.

In No. 1 size engine the steam cylinder is 7 inches diameter by 7 inches stroke, and the indicated horse-power is 30; diameter of "jet" $1\frac{1}{16}$ inch; will throw 350 gallons per minute 160 feet high. The total weight of the engine is 28 cwt. The time for raising steam from cold water to 100 lbs. per square inch is 7 minutes; it has been done in $5\frac{3}{4}$ minutes. The engine is carried on four wheels hung on springs in the usual way. The hose is carried in a box under the driver's seat, which also takes the tools; the framing is of wrought iron, the fore-locking carriage being of the same material. The above class of engines are made in two sizes, and for larger ones Messrs. Shand, Mason, and Co. use three cylinders and pumps as above described, one crank shaft being common to all the cylinders; no fly wheel is required. Great steadiness and regularity is obtained in these engines when working, and on this account they are named the "Equilibrium." For smaller engines than those of the Metropolitan Fire Brigade, one called the "Volunteer" only weighs 21 cwt. The indicated horse-power is about 19; jet $\frac{15}{16}$ inch diameter, will throw 260 gallons of water per minute 150 feet high. Consistent with the necessary strength and safety, the author believes these are the lightest engines ever constructed. These engines are suitable for country towns, and especially where the fire station is situated some distance from outlying farms; on account of their light weight they can be rapidly moved to long distances, and by this means heavy losses from fire in such cases may be prevented.

Steam Floating Engines.

These engines are as a rule much more powerful than land engines, as the weight is not a primary object, nor the space confined for fixing the machinery. The first of this kind was built in 1852, by Messrs. Shand, Mason, and Co., for the London Fire Brigade, is still worked, and delivers about 1600 gallons of water per minute. No. 7 Float is fitted with two sets of engines, one to propel the boat, and one to work the pumps. The dimensions are 80 feet by 14 feet, the indicated horse-power 20; they are capable of discharging 2250 gallons of water per minute to a height of 230 feet with a 2¾-inch diameter jet. There are many forms of these steam floats, but they do not materially differ except as to size and power. The pumping machinery and boilers are the same as for the land engines.

The large increase in the size of the docks in London has induced the use of powerful steam tugs for moving about shipping. This has led to the placing of a steam fire engine on board without separate boiler, but supplied with steam from the boiler of the propelling engines. The London and St. Katherine Dock Company, the largest in London, has now in use five tugs fitted in the above manner. These engines are placed horizontally, each consisting of two cylinders, 20 inches diameter, with double-acting pump of 8¼ inches diameter, the stroke being 10 inches. Any speed up to 200 revolutions per minute can be got out of them, the quantity of the highest speed being about 1400 gallons per minute.

In the description given of the above steam fire engines no discussion is entered into as to the various trials that have taken place, as it would take too much space, and be beyond the scope of this book.

Engines of this class have been used for emptying reservoirs, and in one case 1500 gallons of water per minute have been discharged, in pumping from the reservoir into an open shoot and not under any "head."

They are also applied to steam vessels, and are specially constructed for this purpose. In one tried at Portsmouth Dockyard 720 tons of water per hour were pumped from 22 feet 6 inches below the suction valves, under a pressure of 25 lbs. per square inch. There are three steam cylinders, each

10 inches diameter by 13 inches stroke, placed vertically over three bucket and plunger pumps; the buckets are $17\frac{3}{4}$ inches diameter.

In one fixed on board the *Hercules*, steam was raised to 100 lbs. per square inch ten minutes from the time of lighting the fire, and 1120 gallons of water per minute were discharged 200 feet high; the jets were two 1-inch, one $1\frac{1}{8}$-inch, and one $1\frac{1}{16}$-inch diameter. The speed of the engines is about 84 revolutions per minute.

It need hardly be pointed out, the great value of steam floating fire engines where there is much shipping, as in docks, harbours, &c.; and also for extinguishing fire at wharves alongside the river, as the amount of water at command is unlimited, and the power of the machines larger than land engines.

Portable Force Pumps.

A very convenient pump of this class, suitable for pumping out cesspools, small tanks, &c., is made upon the following plan. The barrel is of cast iron, open at the top, the piston being solid, and packed with double leathers. The barrel is fixed at the base to a valve box fitted with suction and delivery valves; these are leather clack valves, and are made of very free area. Over both the valves bonnets are provided for giving rapid access to the valves in case of choking, &c. The valve box has feet cast on, and is fixed to a frame mounted on four wheels, the front ones being made to swivel. A fulcrum arm is cast upon the top of the barrel, and the pump worked by a long wrought-iron lever working on a pin carried by the fulcrum; at each end of the lever are eyes, into which are fitted long round wood handles; either two or four men can work at one pump. The suction pipe is canvas or indiarubber, with a wire core through it, and attached to the pump by "unions." The delivery pipe is indiarubber, canvas, or leather, and fixed in the same way. These pumps discharge a large quantity of water or sewage, are very simple in construction, portable, quickly set to work, and not liable to get out of order. They were first introduced by Messrs. George Waller and Co., and have been extensively used for about thirty-five years. The author cannot too highly recommend them, having had much experience in their use.

Tar Pumps.

Force pumps are sometimes used for pumping tar at a gas-works, but are not to be recommended for this purpose. There are very few cases in which the tar has to be raised more than 30 to 35 feet above the pump. In the author's practice he has always preferred to use "lift pumps," as described at p. 7. They are more regular in their action, not so liable to get choked in the valve chambers, the wear and tear is less, and they are not so complicated.

Creosote Pumps.—Force pumps are used to force creosote into vessels or cylinders containing timber sleepers, &c., for preserving them. They are made with cast-iron barrels and gun-metal plungers, the general details of the pumps being as before described (p. 17).

They are either used singly or in batteries of three, four, and six in each set. All the valves must be gun-metal, and of the spindle kind; only small lift should be given to them, and an adjusting screw provided on each bonnet to regulate this.

The suction and delivery pipes of each pump are usually separate. Air vessels should be fixed on the delivery pipes; these should be of cast iron, and of ample size. Safety valves must also be provided, to relieve the pumps in case of any stoppage. Pet-cocks should be fitted on the suction and delivery pipes, to test the action of the pumps. The speed of working must be slow; for 3-inch and 4-inch pumps (the sizes generally used), say 40 strokes per minute.

CHAPTER III.

SUNDRY PUMPS.

Centrifugal Pumps are suitable when the water is near the surface and the height to be raised above the pump small. The most efficient are "Appold's" and "Gwynne's"; they have to be driven at a rapid rate.

They can be economically employed in the drainage of land such as in the fen or marsh districts, and in emptying docks and reservoirs.

They are either driven by a strap from shafting, or by a steam cylinder attached direct to the pump. The form of pump varies according to the circumstances of the case.

Centrifugal Pumps, on the "Appold" Plan, made by Messrs. Easton and Anderson.

These pumps have been used for pumping ship canals, draining meres, emptying dry docks, &c. Examples will now be given of machinery of this kind executed, with the leading dimensions and working results. It will be observed that most of the plant is upon a large scale, and the quantity of water discharged is also very large. The author considered it would be more useful to describe such kind of works, to show the capability of this class of pumping machinery.

For Drainage Purposes.

Pumping Station on the Amsterdam Ship Canal.—There are three sets of machinery, each as follows:—A pair of vertical cylinder condensing engines drive an overhead shaft with cranks at right angles, one at each end, which carries a bevel wheel between the frames, gearing into a bevel pinion on the

upper end of the vertical spindle of the centrifugal pump, which has a double inlet fan. Cylinders are 2 feet 6 inches diameter, by 2 feet 6 inches stroke. Number of revolutions per minute = 52, indicating about 260 horse-power. The centrifugal pump fan is 8 feet diameter, by 2 feet 11⅝ inches deep. Number of revolutions per minute = 92·5, lift = 9 feet 10 inches. Discharge = about 230 tons per minute each pump.

WITHAM DRAINAGE.—Two sets of machinery like the last, but with different size of fan and lift. Cylinders 2 feet 6 inches diameter by 2 feet 6 inches stroke. Mean number of revolutions per minute = 38·7, indicating 196 horse-power. Centrifugal pump fan 7 feet diameter by 2 feet 3 inches deep. Number of revolutions per minute = 68·8, lift 4 feet 8 inches to 6 feet 1 inch. Discharge = 356 to 395 tons per minute each pump. Efficiency = 59 to 64 per cent.

WHITTLESEA MERE.—A double cylinder, compound, condensing beam engine, with an internal gear spur rim on the fly-wheel, gearing into a pinion on an intermediate shaft, which carries a bevel wheel at its other end, gearing into a pinion on the upper end of the vertical spindle of the centrifugal pump, which has a single inlet balanced fan. Cylinders 15 inches diameter by 3 feet 1½ inch stroke, and 25 inches diameter by 4 feet 6 inches stroke. Number of revolutions per minute = 32, indicating 113 horse-power. Centrifugal pump fan 6 feet diameter by 1 foot 4 inches deep. Number of revolutions per minute = 92·7; lift 10·114 feet. Discharge = 88 tons per minute, = 60·4 horse-power water lifted. Efficiency = $\frac{60 \cdot 4}{113} \times 100$ = 53½ per cent.

REDMOOR DRAINAGE.—To drain 1800 acres, the annual rain-fall being 24 inches, and the maximum rainfall noted having been 10¼ inches in 24 days.

A 14 horse-power portable engine, by means of an intermediate shaft with a universal coupling at each end, drives a horizontal shaft which carries a bevel wheel gearing into another wheel on the upper end of the vertical spindle of the centrifugal pump, which has a single inlet balanced fan. Centrifugal pump fan is 3 feet 4 inches diameter by 8¾ inches deep.

Lift varies from 5 feet to 13 feet. Discharge is 6500 gallons at the mean lift.

NOTE.—The single inlet balanced fans are simpler in construction, more economical, and more advantageous than the double inlet fans.

DOCK PUMPING.

PORTSMOUTH NO. 11 DRY DOCK IN H.M. DOCKYARD.—The same arrangement as in cases 1 and 2 of drainage machinery, with the same sized engines. Ratio of gearing, 89 : 36. Centrifugal pump fan, 6 feet 6 inches diameter by 1 foot 8 inches deep. Work done:—The dry dock, holding 19,000 tons of water, was emptied in 2½ hours; the maximum lift at the end of pumping being 26 feet 3½ inches.

DRY DOCK AT THE IMPERIAL DOCKYARD AT CRONSTADT.—There are four sets of machinery, each as follows:—One horizontal condensing engine, with air pump worked by continuation of piston rod through bottom cover of cylinder, drives a vertical spindle centrifugal pump by a pair of bevel wheels direct; ratio of gearing, 3·27 : 1. The pump has a single inlet, balanced fan. Cylinder, 27 inches diameter by 3 feet stroke. Centrifugal pump, 4 feet 10 inches diameter by 10 inches deep. Work done by four pumps together:—The dry dock, holding 34,000 tons of water, was emptied in 1¾ hours; the maximum lift, at the end of pumping, being 39 feet.

SALTERSCROFT GRAVING DOCK, GLASGOW.—There are four sets of machinery, each as follows:—A double cylinder, non-condensing engine, with cylinders placed at right angles, acts direct on to one crank at the upper end of the vertical pump spindle of a centrifugal pump, which has a double inlet. Cylinders, 14 inches diameter by 15 inches stroke. Fans 5 feet 6 inches diameter by 10 inches deep. Work done by all four pumps, acting together:—The dry dock, holding 26,400 tons of water, was emptied in 2⅓ hours; the maximum lift at the end of the pumping being 23 feet.

Centrifugal Pumping Machinery made by Messrs. J. and H. Gwynne, of Hammersmith.

The author has selected a few examples from works executed by this firm, and gives hereafter data of working.

FERRARA MARSH DRAINAGE (ITALY).

The amount of work to be done was to raise about 2000 tons of water per minute, about 7 feet 3 inches mean lift. There are eight pumps, in pairs, each set being driven by a separate engine. When raising the mean height (7 feet 3 inches), *each* of the pumps will discharge 57,000 gallons of water per minute, or for the eight pumps nearly half a million gallons of water per minute.

Each pair of pumps is driven by a compound engine, the pumps being placed on either side. The pump shafts are steel, 8½ inches diameter. The discs of centrifugal pumps are 5 feet diameter. The suction and delivery pipes 54 inches diameter.

The engines have L.P. cylinders, 46⅝ inches diameter, and H.P., 27¾ inches diameter by 2 feet 3 inches stroke. The cylinders are jacketed. The cranks are placed at 130°.

The L.P. cylinder exhausts into a pair of surface condensers having each about 750 square feet of surface. The air-pump is single acting, 19 inches diameter and 12 inches stroke.

After working two years, the official trials gave the following result:—Consumption of fuel, 2 lbs. per indicated H.P. The tract of country reclaimed extends over 200 square miles, and the work is performed by 4 pairs of these direct-acting pumping engines.

DRAINAGE IN HOLLAND.

Polder Grootslag (Andyk).—A pair of 36-inch horizontal direct-acting centrifugal engines.

The machinery raises 30,818 gallons of water per minute a height of 10 feet 6 inches. Consumption of fuel, 3 tons 13½ cwt. in 24 hours. Just recently a 39-inch "Invincible" pumping engine, to discharge 90 tons per minute, has been added.

The following list will give an idea of the immense scale on which this class of machinery has been applied and the quantity of water raised in each case:—

Names of Places where Centrifugal Pumps and Pumping Engines have been Supplied.		Quantity of Water Raised per Minute.
		tons.
Ferrara	Italy	2,100
Hauvill	Denmark	230
Sajfoji Inland Water Regulation Company	Hungary	100
Workümmer	Holland	46
Parreagaster Meeren	"	20
Loosdrecht	"	140
Polder, Grootslag (Andyk)	"	150
Do. do.	"	90
Legmeer Plassen	"	150
Bijlmer Meer	"	50
Middel Polder	"	50
Meidrechtsche 1ste Bedijking	"	45
Zwammerdam & Reewyk (Tempel)	"	14
Berkmeer	"	24
Noord-Einder Meer and Sappe Meer	"	24
Baars-dorper Meer	"	15
Houtrak Polder	"	50
Crobsche Uiterwaarden	"	20
Meethuijser Meer	"	14
Starn Meer	"	30
Schager Waard	"	20
Wieringer Waard	"	6
Waard en Groet	"	54
Vosser en Weerlaner Polder	"	14
Slooter Polder	"	20
Purmerland	"	39
Middelburger Polder	"	20
Roomtuin	"	15
Watergraafsmeer	"	32
Polder Nieúwkoop	"	25
Ook Meer	"	45
Temporary—Water Verversching Amsterdam	"	120
Banne Purmerend	"	28
De Enge Wormer	"	14
De Vereenigde Polders van Capelle a/d Yssel	"	27
Waardenburg (Uiterwaard)	"	14
Polder Rhoon	"	28
Polder Herwynen	"	56
City of Zutphen	"	10
Johanna Kerckhoven Polder	"	39
Polder Spanbroekerkaag	"	27
Polder Venhuizen en Hem	"	60
Lutkemeer	"	27
Houterpolder	"	60
Bullewijk	"	60
Waterschap de Geel	"	27
Uiterwaarden Hagestein	"	27
Polder Acquoy	"	40

These engines and pumps are also largely used for irrigation in Egypt, India, South Africa, &c.; also for pumping, graving, and floating docks.

They are also suitable for raising sewage; there being no

valves, any solids that are passed through do not interfere with the action of the pumps.

An "Invincible" pump with 36-inch suction and delivery pipes will discharge 20,000 gallons of water per minute; one with 48-inch pipes 40,000 gallons per minute, and one with 60-inch pipes 100,000 gallons per minute.

Airy and Anderson's Patent Spiral Pumps (Drawing No. 5).

The patent spiral or screw pump is an apparatus by which liquids are screwed up an inclined plane at a low velocity and without the intervention of pistons or valves of any kind. The duty performed is higher than is possible for low lifts, with any other arrangement of pumps.

Experiments have shown that 85 per cent. of useful work can be realised, and in the larger pumps, worked by compound condensing engines, water has been raised with less than 3 lbs. of coal per horse-power of water lifted per hour. The construction of the pump is very simple, and consists of a sheet-iron cylinder, down the centre of which runs a core. Between the two are wound three or more spiral blades of a peculiar form, made of sheet iron. The ends of the core terminate in gudgeons of suitable construction, and revolve in pedestals, the lower one is fixed under water, and the upper one on a bridge spanning the delivery opening. The pump is generally driven by a spur or bevel wheel at the top attached to the casing, and geared into by a pinion and shaft, which may be driven in any convenient manner, either by a portable or fixed engine. A diaphragm makes a water-tight joint between the upper end of the pump and the delivery canal. The water level on the inlet side may rise and fall above the minimum level without affecting the efficiency of the pump, but on the delivery side the water must not rise above a certain height, nor can it fall much below it without loss of effect, hence these pumps are not applicable where there is great variation of level on the delivery side. The pumps can be made of any size to deliver from 1500 gallons to 32,000 gallons per minute, but the height for each lift should not exceed about 20 feet.

The patent spiral pumps deliver very nearly the same per revolution whatever speed they are run at, hence they make very accurate meters. It is only necessary to fix a counter on

each pump in order to have a complete record of the quantity of water raised in any given time.

The pumps do not require charging, and may be run at very slow speeds.

Chain Pumps.

These are rather a clumsy contrivance, they are principally used to pump water from excavations, and consist of two pipe legs or shoots with top and bottom wheels; the buckets are attached at intervals to an endless chain. Motion is given at the top by engine power; the water is delivered into a shoot at the top. They are very noisy and cumbrous, and far from economical as to the consumption of fuel. They take some time to put together ready for work, and are liable to break down, a very serious consideration when pumping for works in progress.

They, however, possess one advantage; they can pump gritty water and almost liquid mud without any detriment to the apparatus, and partly on this account are a favourite class of pump with some contractors. The author does not recommend their general use, although they may be useful in special cases.

Sewage Pumps.

Lift or force pumps, single and double-acting, are used for this purpose, and do not much differ from water pumps, except as to details hereinafter named; they are best made with open top barrels, the pump buckets packed with double leathers, and the valves leather and of the "clack" kind; they should be easily accessible. To pump a large quantity, the pumps should be treble barrels, worked by crank shaft, and either driven by a strap or by wheel gear from shafting, or steam cylinders may be attached direct.

A single pump may be made, fixed horizontally and worked direct from the end of a steam-engine cylinder, as described at p. 26. The pumps in this case are made double-acting, and on the ram and piston plan, packed either with leather or gasket. The passages must be made very free in area, the valves with rather small lift, and as described for the Portable Engines at p. 24.

Pumps, 24 and 30 inches diameter and 36 to 48 inches stroke and upwards, on this plan, have been used for pumping the sewage of towns.

The speed of buckets or plungers should be slow, say not to exceed 120 to 150 feet per minute; otherwise much slip takes place, and the shocks in the pumps will be heavy. The suction pipe must be carefully protected at the bottom by a "rose" and grid, to prevent any sticks and dirt getting into the pumps.

When the pumps are on a large scale they are usually worked by high- and low-pressure and condensing engines, and in this case are very economical as to consumption of fuel in the boilers compared to the work done. As pumps for this class of work are not special in other respects than those named above, sufficient detail is given.

CHAPTER IV.

GENERAL DETAILS AS TO LIFT AND FORCE PUMPS, SUNDRY GEAR, ETC.

THE VERTICAL DEPTHS OF SUCTION should not exceed 25 feet; the horizontal distance from the pump is not taken into account, except as to the extra allowance named hereafter; but when the source of supply is some distance from the pump, and the pipes underground, the joints of the pipes must be very carefully made, and tested before the ground is covered in.

DELIVERY MAINS.—The lengths of the horizontal mains from the pumps to reservoirs must be taken into account, and 12 feet extra lift per mile allowed for friction; this is supposing the area of the delivery main pipe is ample; otherwise the load on the engine will be much increased. In arranging for the main pipe for water supply to a town, this is a very important consideration if the water is to be pumped economically; small pipes in such cases increase the friction very much.

HORSE-POWER REQUIRED for pumping with ordinary well pumps.—Multiply quantity of water to be raised in gallons per minute by 10 lbs. and by head in feet $\div$ 33,000 + $\frac{1}{5}$ for friction and slip of valves = horse-power.

STAND PIPES are sometimes used, instead of air vessels, for water supply of towns, the height of the pipes being in excess of the highest part of the district to be supplied. They possess these advantages: they give a uniform dead load upon the mains, and are not liable to the accidents that sometimes arise from the fracture of an air vessel. They are, however, rather un-

sightly as well as costly, and are not so often used as formerly; the pipes may be enclosed in a brick tower or shaft, which may be made an architectural feature.

The LEATHER for pump buckets and valves should be oil-dressed, and of the best kind, cut out of the middle of the back, and of even thickness. To make good leathers, iron moulds should be used, the material being softened in moderately hot water, then *gradually* pressed, extra pressure being put on at intervals. When the plunger is well home, the leathers should rest several hours in the press before taking them out. When duplicate leathers are kept in stock, they should be in a dry place, and occasionally oiled to preserve them; they should never be stacked in a room where much gas is used, as the leather is much injured if kept in such a place for any time.

LEATHER PUMP VALVES.—When used, the thickness will vary with the size of the pump and the "head" of water. It is always very advantageous to face the leather on the side it seats upon the valve, to ensure a perfect joint. For large valves, hippopotamus and rhinoceros hide may be used with great advantage; they make splendid valves, and last many years. In all cases gun-metal plates should be riveted on, to make them fall in the case of "flap valves," and to keep them rigid when the valves rise upon centre pins or on the pump rod, as described at p. 3. These plates should be carefully proportioned as to thickness and surface, and well fixed to the leather.

PIPES used for town supply or in public places sometimes have the sockets bored, and coated on the inside with Dr. Angus's composition. For long mains and pipes above 12 inches diameter, 12 feet lengths may be used; they are generally made 12 feet exclusive of sockets.

They will bear a pressure of 160 to 180 lbs. per square inch, which is about the greatest pressure in any town, in the supply main. When turned and bored pipes are not used, the sockets are caulked with lead.

The SPEED of water through town mains may be taken at 2½ to 3 feet per second when working economically; this speed should not be exceeded or the friction will be much increased.

The table following gives the weight of socket pipes for

water purposes. All sizes up to 2½ inches diameter [illegible] lengths; 3 to 12 inches diameter are 9 feet, and all above, 12 feet lengths; all lengths are exclusive of sockets. It is very requisite to have pipes for water purposes of good quality, and the proper thickness or weight per yard; also that the sockets are well proportioned to make a good joint and take the proper amount of lead. The table will also be found useful in making estimates of cost.

STANDARD WEIGHTS OF MESSRS. BAILEY, PEGG, AND CO.'S SOCKET PIPES FOR WATER PURPOSES.

ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.
2	1 21	6	2 2 0	12	6 2 0	20	17 0 0
2½	2 14	7	3 0 0	14	10 1 0	22	18 2 0
3	3 21	8	3 2 0	15	12 0 0	24	22 1 0
4	1 1 21	9	4 1 0	16	13 1 0	30	30 0 0
5	2 0 0	10	5 0 0	18	15 2 0	36	35 0 0

BENDS (Socket).

ins.	qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.
2	26	4	2 8	7	2 0 21	10	3 3 0
2½	1 6	5	1 0 0	8	2 2 0	12	4 0 0
3	1 11	6	1 1 21	9	3 1 7	14	5 3 0

TEE PIECES (Socket).

ins.	qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.
2	1 18	4	3 21	7	2 0 21	10	4 1 0
2½	2 7	5	1 0 21	8	2 2 0	12	5 1 18
3	2 24	6	1 2 10	9	3 2 14	14	6 3 14

STANDARD WEIGHT OF FLANGE PIPES.

6-feet.		9-feet.					
ins.	qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.	ins.	cwts. qrs. lbs.
2	1 21	3	1 0 0	7	3 1 14	10	5 2 0
2½	2 7	4	1 2 0	8	3 3 14	12	6 3 0
		5	2 0 0	9	4 2 0	14	9 0 0
		6	2 2 0				

VALVES.

The bodies are made of cast iron, in one piece, except the cover, which is bolted on, the joints being faced; the doors are wedge-shaped, and may also be cast iron, but with gun-metal faces, working on faces of the same material let into the valve

si... ...es are strongly ribbed, ...pening and closing against ...e to use flange valves, as they ...ed in case of accident. They are ...s with flange and spigot or socket con... short lengths. All valves should be tested, ... under a pressure of 200 lbs. per square inch. ...y false economy to use indifferent valves, and unfor...ately in this and other cases before named the competition is so fierce, that very poor valves are in the market, and too often find their way into use, where parsimony, and not efficiency, is the chief consideration. Much care is needed in the selection of suitable valves, perfect as to workmanship and simple in construction.

Water Meters.

A small compact meter is made by Messrs. Guest and Grimes. It is much used by the water companies, and is deemed by them a reliable instrument.

When, however, there is sufficient space, the author prefers Kennedy's patent meter. It works with very little friction, and causes but small loss of pressure; this is a matter of great moment, especially where high tanks have to be reached, or where the water pressure is to be used direct from the mains, for hydraulic lifts or engines.

There are several other kinds, but in the author's practice he has found those named above the most reliable. In most instances the water companies have the power to put in any kind of meter they approve of, and it must be fixed by them and according to their regulations.

Meters are very useful in large places, for the purpose of checking waste of water, as in most instances, the proper average quantity that should be used can be arrived at. The "dial" should be read at stated times, once per day or week, according to the necessities of the case; this always has a good moral effect upon the workmen or attendants of a works or other place, and also acts as a preventive of waste. Plenty of water is a necessity, but waste under any circumstances should be prevented, especially in town supply, where the quantity available is in many cases limited in proportion to the requirements of the place.

TANKS FOR STORAGE, ETC.,

when fixed on the top of any building, should be of cast iron, with planed joints, the pitch of the bolts not more than 6 inches. The depth of the side plates should not exceed 4 feet to 4 feet 9 inches, and where possible the total depth of the tank should not exceed 10 feet. For capacities of about 20,000 gallons, the bottom plates should be $\frac{5}{8}$-inch to $\frac{3}{4}$-inch thick, and the sides $\frac{9}{16}$-inch to $\frac{5}{8}$-inch. The flanges 3 inches wide, $\frac{3}{4}$-inch thick, bolts $\frac{3}{4}$-inch diameter, and 4-inch centres, with fillets $\frac{5}{8}$-inch thick between each bolt hole. Stays should be wrought iron, or copper, and for tanks not exceeding 3 feet 6 inches in depth, one set at the top will be sufficient, attached to the side flanges with two $\frac{1}{2}$-inch wrought-iron plates taking 2 bolts; the diameter of the stay not less than $1\frac{1}{4}$ inch and the pins the same size, to allow for corrosion, which nearly always takes place after a short time, especially in some waters which have a chemical action upon wrought iron.

When the depth of the tank exceeds the dimensions named above, they should have 2 or 3 tiers of stays. At the centre of each stay rod a long nut should be provided to tighten up. Each joint of the bottom plates should rest on girders, and be bedded carefully. The inside of the tank should always be painted, and where there is much deposit, this must be done once or twice per year.

All pipe outlets should be provided with strainers of cast iron, with fine holes drilled in them, and should stand up, say 2 to 3 inches, from the bottom of the tank, to prevent any deposit from getting into the pipes and valves.

The rising or delivery main, when possible, should deliver *over the top* of the tank. An overflow pipe of copper should be provided, with trumpet-shaped top, and gun-metal hollow plug and seat at the base. These pipes must always deliver where *they can be seen,* and must never be connected into a drain. A flat float made of copper should be provided, and a gauge placed in a conspicuous place to show the quantity of water in the tank and to prevent waste. A warning pipe should also be provided, and carried to the engine room, to give notice when the tank is full. The top of the tank should always be covered, and when placed outside the roof of a building, there should be a wood cover made of boards $1\frac{1}{4}$-inch thick, grooved and tongued,

and traversed with 1¼-inch boards, with a layer of thick roofing felt placed between, and strongly battened on the under side. When so protected, the water inside is seldom touched by frost. A manhole and door is provided to permit of examination and cleaning. It is preferable, wherever possible, to keep the flange joints of the plates *outside* the tank, as it is much easier to keep the interior clean, and the water then cannot act on the bolts and nuts.

When tanks rest on brickwork walls and cross girders, the latter should have wide stone templates under them, and if possible, the wall finished with stone coping well bedded in cement.

Hollow brick walls should *never* be used to support water tanks; they are not fit for the purpose, and many serious accidents have taken place by the failure of the walls when they have been used.

WATER TOWERS constructed in brickwork or masonry may be made circular or octagonal in shape, with a centre hollow pillar, in which a staircase may be formed; it is not only convenient, but adds much strength to the centre support. Radiating girders of wrought iron to carry the tank should be fixed, resting on the outer walls. At the centre of the tank a hole equal to the internal diameter of the centre pillar should be left. For the cover of the tank, an iron roof should be constructed, resting upon the outer wall; this may be covered with galvanized iron. The thickness of the walls will depend upon the height and weight of water in the tank, and the soil it rests upon; no rules can be given as to this, as a special design must be made in all cases.

WROUGHT-IRON TANKS may be used, when of moderate capacities, especially where light weight is an object; they should not be less than $\frac{3}{16}$-inch to ¼-inch thick, riveted at the corners and bottom to angle iron, with T-iron stays on the outside. The top of side plates (for large sizes) should always be provided with an L-iron ring, to stiffen same, and to which a cover may be riveted when it is desired to keep the tank closed. The internal tie bolts and stays must be attached to the side plates, opposite the T-iron vertical outside stays. The fittings and supply pipes, &c., will be the same as for cast-iron tanks.

The girders to support wrought-iron tanks should not be more than 2 feet centres, and should come as nearly under the joints as possible. The tanks must take a fair bearing upon the tops of girders by adjusting with iron packing pieces; this avoids straining the joints.

DRIVING GEAR FOR PUMPS.—As before stated, p. 5, the author prefers, wherever possible, to communicate motion by using straps, except for well pumps, where tooth gear should always be used.

CLUTCHES for throwing out of gear, may be of the ordinary kind, with two nogs tapered at the points; they should fit close, to avoid any rattle and shocks to the pumps. Cone clutches may be used; they should be of rather large diameter, to give a good grip without any undue strain upon the shafting. Patent grooved friction clutches may also be employed; they act very well when properly proportioned, and the levers and other parts suitably designed. *In all cases* the speed of the engines should be slowed before throwing the machinery into gear; otherwise the sudden shock that is sure to take place may cause a serious fracture.

When the well pumps are at some distance from the engine, they may be driven by a chain, or a round rope protected from the weather, or a small separate engine may be employed; the steam can be carried any distance up to 500 feet from the boiler, when the pipes are well protected by composition and laid in a close trench, without much loss of pressure or condensation. In practice it has been found not more than 2 lbs. pressure per square inch is lost in such cases.

ARRANGEMENT OF ENGINES AND PUMPS.

For pumping for town or other large purposes, two engines should be provided, one fixed on each side of the engine house, with spur-wheel gear from the crank shaft of the engine to work the three-throw crank shaft of the pumps. Clutch motion should be applied to admit of either engine working each set of pumps, or the combined engines working the two sets of pumps. The air vessel can stand in the middle between the engines. The driving toothed pinions should be pitched and trimmed, and the spur wheels upon the three-throw crank shaft geared with wood teeth. Spare pinions and crank shafts

should be kept ready, the pinions made in halves for readily fixing on the crank shafts in case of a break-down. A duplicate crank shaft, interchangeable for either set of pumps, should also be provided; also duplicate valves for the pumps, and spare pump rods and extra buckets.

In small places, the engine can be made with a double crank, with the pinion keyed on the outside of the bed plate, and working direct on to the spur wheel on the pump shaft.

The wheels should work under iron guards, and the top of well protected by a rail, or covered over by wood boards or iron plates resting on girders.

A neat and simple arrangement is to gear from the crank shaft on to an intermediate shaft, passing through the brick-work bed of the engine to the crank shaft of pumps working below the floor line; in this case the top of well can be closed in with iron plates as named above, and a trap-door left in same to gain access when required.

CHAPTER V.

AIR PUMPS, BLOWING ENGINES, AND COMPRESSORS.

Air Pumps.—These pumps are used for various purposes, and the details vary according to circumstances; some of the principal are hereafter described; where they do not vary much in design, when they are used for some other purposes, they are not specially mentioned here.

Air Pumps for Vacuum Pans.—The barrels should either be gun-metal, or cast iron lined with the former, say $\frac{3}{8}$-inch to $\frac{1}{2}$-inch thick. The buckets should have metallic packing, similar to the piston ring of a steam engine cylinder; those made on the locomotive plan, viz. a single ring, with a tongue piece and back plate, answer the best. The ring should not have too much spring, and must fit the cylinder accurately. The valve of bucket may be gun-metal, and made to rise on the rod, or of red indiarubber, and attached to a gun-metal plate, as described at p. 3. The suction and delivery chambers are bolted on to the barrel, and the valves made in the same way. Where indiarubber is used the valve seats and the top of bucket are made with grids; ample area must be given to the valves.

The diameter and stroke of these pumps vary, according to the work to be done, from 10 inches to 30 inches diameter, and 24 inches to 42 inches stroke. The speed should not exceed about 30 to 40 strokes per minute for the largest size, to allow the valve to close. The author has, however, worked pumps of this kind, 18 inches diameter by 30 inches stroke, up to 70 and 75 strokes per minute. The rods should be of gun-metal or steel, either secured to the bucket by a key or by a solid collar in the rod, clipped by the "junk" ring of the bucket. The valves are sometimes made upon the "hat-band plan"; they give very good results; the valve seats in this case are a cylin-

drical grid, with a ring of thick indiarubber round same. They are not, however, so good as the other kinds named before, and are seldom used.

Air Pumps, to work dry, for chemical vacuum pans, are made much the same as described at p. 47. The valves must not be made of indiarubber, but leather, say ½ inch to ¾ inch thick, according to the size of the pump, fitted in the same way, and made to rise on the bucket rod, as before described. In some cases the valves are made of gun-metal, and either to rise upon the rods and pins, or of the spindle kind. With pumps fitted with leather valves, the author has maintained a vacuum of 29½ inches. Flap valves are not often used, on account of the noise in working.

It is almost unnecessary to add, the work must be of the highest class, and the chambers where the valves work and other parts well proportioned as to area.

To obtain a high vacuum, especially when the pumps do not exceed 6 inches to 8 inches diameter, they may be made the same as a force pump; the piston is then allowed to work within ⅛ inch to $\frac{3}{16}$ inch at top and bottom of the cylinder, and the chambers kept small and close together to save loss of air. The forms of these pumps vary to suit circumstances; they may be made horizontal and double acting; when small, they should always be made in gun-metal; a much more efficient pump is obtained in this way, and does not as a rule cost much more than if made of cast iron, with gun-metal valves and plunger.

Air Pumps for condensing steam engines, and for vacuum pans, or where injection water is always used.—The pumps are sometimes sunk in a tank of water, and are open at the top, the water overflowing at the top receiver. They give very good results when worked upon this plan; the wear of the rods and other parts is less, and the vacuum can be well maintained; the same remarks as to speed equally apply here. This is a very old type of pump; it still, however, gives as good working results as any other kind, and from the facility of keeping packings tight, is often preferred.

Air Pumps for diving purposes.—To convey air to divers, and to "diving bells" under water, the following kinds of pumps are used; the most effective are those made by Siebe, Gorman, and Co., of which the following is a description:—

The double-action pump consists of two barrels fixed in a box, and worked by a two-throw wrought-iron crank shaft, with fly wheel and winch handles. Two cast-iron side frames carry the crank and shaft. The pumps are placed in a copper tank or box filled with water to keep them cool; each pump will deliver 135 cubic inches of air per revolution of the crank, and can compress the air to 240 lbs. per square inch. The pistons of the pumps are composed of two leather cups, inverted. There are two valves at the top of the cylinder, one for the inlet of air and one for outlet, there are also two valves at the bottom.

By these pumps, air can be supplied to two divers at the same time and working at different levels. Each diver in this case is in direct communication with *one* of the cylinders; when, however, work is being carried on under water to a depth of 90 feet, only one man should be supplied with air from the same pump. The pumps are enclosed in a strong teak case. There is a very ingenious arrangement of valves for distributing the air to the two divers, but as it is of a somewhat complicated nature it cannot be entered into here.

These pumps are fitted in the most careful manner, and are very effective in their action. Only machines of the highest class should be used for this purpose, as it must be remembered the lives of the divers depend upon the perfect action of the pumping apparatus and gear.

Three-cylinder pumps are also used; these are more effective in action than the above, but only *one* diver can be supplied from them at *one time*. The cylinders or barrels are of gun-metal, and open at the top. Each piston is provided with a valve for the admission of air; the outlet is at the bottom of the barrel. The cylinders are fixed in a tank of water as before. The working gear is by crank shaft as before described.

The air pipes are of indiarubber, with iron wire embedded, and in lengths of about 30 to 40 feet; the diameter is about $\frac{5}{8}$ inch. They are fitted together with gun-metal joints.

AIR PUMPS FOR EXHAUSTING AIR FROM CHAMBERS or from large cylinders and vessels, are made sometimes horizontal, as described for the force pumps, at p. 26, and are worked direct from the end of the steam cylinder, being fixed in the same bed plate. The valves are gun-metal, as before described

for engine air pumps, but the piston of the cylinder is solid with metallic ring, and acts in the same way as a force pump. The pumps are usually large in diameter, and made with a stroke about double the diameter; they are usually made double acting.

PUMPS OF THE SAME KIND, BUT MADE VERTICAL.—A very good form is one made by Messrs. George Waller and Co., of Southwark, where the steam cylinder is fixed on one side, and the air pump on the other side of the bed plate on an entablature form of engine. These pumps are used for exhausting air from pickling cylinders for timber preserving; they are made 18 inches (and above) in diameter, and are worked rapidly; the cylinders, from which the air has to be exhausted, are wrought iron, and 6 feet to 7 feet diameter, and 50 feet to 70 feet long. Only metal valves should be used in these cases, on account of the chemical vapours which are drawn away from the cylinder, which would act upon indiarubber or leather valves. The force pumps for driving in the sulphate of copper, creosote, or any other chemical used in the process, are fixed upon the same bed plate. They are made very strong, and the parts well proportioned, to avoid the chance of a break-down, which, in processes of this kind, is a very serious consideration.

AIR PUMPS FOR FORCING AIR INTO APPARATUS.—These are made upon the same plan as plunger force-pumps, described at p. 17. They are usually made of gun-metal, and with plungers 3, 4, and 6 inches diameter according to the work to be done.

They are sometimes worked in sets of three, in a frame, and by cranks, driven either by strap from shafting or by a steam cylinder attached direct on the pump frame as before described. The area through the valves should be about one-fourth of the area of the plungers; only small lift must be given to them. The face of the valve seat should be conical, and with small surface; they must be a perfect fit to prevent any escape of air. The plungers must fit in the gland and collar bushes, and be well packed. Taking 3-inch diameter pumps as an average size, they may be worked up to 80 strokes per minute. Safety valves must be fitted to the pipes, to give relief in case of undue back pressure.

LARGER sizes, from 12 inches diameter to 24 inches and above, are made with solid pistons, and on much the same plan

as described at p. 26. The piston may have metallic or hemp packing. The pump barrels in this case are made of cast iron, and the valves of metal, indiarubber, or leather; the piston or pump rod should be steel. All the joints of the pump and pipes should be faced, and the joints made with thin drawing paper well oiled. The passages must be kept compact to save loss of air. It must be borne in mind, it is more difficult to make the joints of vessels to retain air than any other fluid; and if the receiver is of wrought iron it should be double riveted. It is also desirable to plane the edges of the plates, and drill all the holes. There are many other purposes for which air pumps of this class are used, but although the details vary with the special circumstances, the general form of the pumps is much the same.

Blowing Engines (Drawing No. 6).—These engines were constructed by Messrs. Hick, Hargraves, and Co., of Bolton, and are designed to supply blast for the Bessemer process; they were made for the Mersey Steel and Iron Company in 1871, and are capable of supplying 1500 cubic feet of air per minute, at a pressure of 25 lbs. per square inch when running at 20 revolutions per minute, and indicating about 440 horse-power.

The blowing cylinders are 54 inches diameter, the steam cylinders 40 inches diameter, and the stroke, viz. 5 feet, is common to both. The admission and expulsion of air from the blowing cylinders is regulated by piston valves placed on the tops of the cylinders; this form of valves is eminently suitable for this purpose, on account of their simplicity, durability, and the small amount of power required to work them. There are, in addition, non-return valves in the eduction pipes, to prevent leakage of air back into the cylinders, in the event of the piston valves getting worn. Steam is admitted, and exhausted to and from the steam cylinders by means of equilibrium lifting valves, actuated by "cams" placed on lay shafts running parallel to the axes of the cylinders, and driven by mitre wheels from the crank shaft. The exhaust valves have a constant motion or lift, but the steam inlet valves may have four lifts by moving the hand levers shown in the drawing, which slide the sleeves carrying the admission cams along the shafts, thus bringing different-shaped surfaces under the toes of the rate rods, and cutting off the steam earlier or later in the stroke.

It will be apparent from the plans that the air cylinders lie behind the steam cylinders, and are bolted down to the same massive frame, thus making it a self-contained machine.

In order to facilitate starting, and also to render a light fly wheel sufficient, two engines are employed, having their cranks at right angles. This plan also ensures more steady and regular delivery of the air, and saves much vibration in the machinery and gear.

Root's Patent Blowing Machines.—These machines are of the rotary class, and in design are on somewhat the same plan as Jones' patent gas exhauster. They can either be employed to exhaust air or gases, or for blowing engines only, for smithies, blast furnaces, or for the purpose of ventilating mines; they are also used for forcing air into drying rooms, for working pneumatic despatch tubes, and other purposes.

The machine is constructed with two duplicate rotary pistons; they are fixed upon separate shafts, and work in a cast-iron case, having inlet and outlet openings, either at the top and bottom or at the sides. The two pistons are geared with tooth wheels, and work closely together, but are not in actual contact.

The blowers are also made to work direct from a steam cylinder by two connecting rods, attached to the cross-head, working two crank discs, one being keyed on to the shaft of each rotary piston. The inlet of air is at the top of the casing, and the outlet at the bottom.

These machines are also applied to the ventilation of mines; they do not differ in the system, but have pistons especially adapted for the purpose. One of these ventilators is in use at the Chiltern Colliery, Ferryhill, near Durham; the pistons are 25 feet diameter by 13 feet wide, and are keyed on steel shafts. The blower is driven by a pair of engines, 28 inches diameter by 48 inches stroke; the engines are placed at right angles to the blower, with bevel-wheel gear 9 feet 2 inches diameter.

When running at a speed of 15 revolutions per minute, the air discharged is 87,000 cubic feet per minute. The machine, when worked up to the full capacity, will discharge 200,000 cubic feet of air per minute; at 21 revolutions per minute, discharging 118,272 cubic feet of air, the water gauge being 4·12 inches, the useful effect is 51·4 per cent.

Special Blowers are constructed to work at a pressure of 3 lbs. per square inch, and to discharge 10,000 cubic feet of air per minute. The rotary pistons in this case are turned on the periphery, and the centre part shaped. They are driven by spur gear, and either by strap from a shaft or combined engine, as before described.

For smiths' fires, a pressure of air equal to 12 inches of water will do; melting iron in cupola, 20 inches. The maximum speed of these blowers is from 300 to 400 revolutions per minute.

These machines can be applied to a large number of purposes in chemical works, and for exhausting gas in gasworks. Machines of this class are not very silent in working, but this is a matter of small importance compared with their efficiency and economy in the work done. It would be beyond the scope of this book to enter into any further detail of this class of machine; enough has been stated to show what useful apparatus they are, and how well suited for the special purposes to which they can be applied.

Air Compressors (Drawing No. 7).

These machines are made by Messrs. Hick, Hargraves, and Co., of Bolton, for mining purposes. Each machine consists of a pair of vertical inverted single-acting cylinders or pumps, supported on cast-iron standards. A crank shaft by connecting rods works the pistons of the pumps, the shaft being driven by spur-wheel gear from any convenient engine.

Single-acting cylinders for machines of this design have been found in practice the most effective; two cylinders are, however, used to equalise the resistance, and give a more regular flow of compressed air.

The cylinders are each open at the bottom; the inlet of air takes place at this point in the descent of the piston, and discharged by the closing of the valves on the top of the piston and opening the valves in the top valve plates, the air being discharged through the centre pipe common to both pumps. The pistons are packed with steel rings; the connecting rods are attached direct to same. The crank pins are placed at right angles. The valve plates of the piston and delivery consist of a number of small valves and seats, to which only a limited lift is given; the pistons work up very

close to the top valve plate to prevent loss of air, and the space above the valve is economised as much as possible. The base plate is strong, and the A frames well spread at the feet to give steadiness. The machine is very compact, and being vertical takes up very little floor space. A good foundation of brickwork or masonry is necessary, and long holding-down bolts passing through same. The simplicity of the machine is apparent; the details of the connecting-rod crank shaft being of the same type as usual in engine work; the cylinders are 30 inches diameter by 24 inches stroke. This machine can have an engine attached direct to the pinion keyed on the crank shaft; the two bed plates either being bolted together or cast in one piece. The steam cylinder can be placed either vertically or horizontally to suit the particular case.

Air Compressors made by J. Fowler and Co., of Leeds, for Colliery Purposes (Drawing No. 8).

These compressing machines are horizontal, and consist of a pair of coupled engines with two steam cylinders 34 inches diameter by 6 feet stroke, and the two air cylinders 40 inches diameter by 6 feet stroke. Pressure of steam, 40 lbs., cut off ¼. Air compressed to 40 lbs. per square inch.

The engines are horizontal, of the usual type, with one fly wheel. The valve motion is of the Cornish kind, worked by cams. Steam valve 8 inches diameter, and exhaust 9 inches diameter.

The air cylinders are worked direct off the piston rods of the steam cylinders, the air receiver being placed between the air cylinders. The cylinders are surrounded by water, and are double-acting. The inlet and outlet valves are in the covers at each end. The inlet valves are of the "clack" kind, with leather flaps; there are three to each cover. There are two outlet valves at each cover—mitre valves of gun-metal with deep seats; they are guided at the top spindle, and are fitted with spiral springs to ensure the closing of same. This kind of delivery valve has been found to work the best in practice.

The speed of the pistons equals 240 feet per minute, and the horse-power indicated about 482.

The air receiver is wrought iron, 5 feet diameter by 30 feet long, double riveted, provided with gauge, &c.

The useful effect at 40 lbs. air pressure equals 25·8 per cent., and at 19 lbs. air pressure equals 45·8 per cent.

Engines of this kind are very useful for supplying air to work hauling and other machines for underground work. As they are of a type well known, no further description seems necessary. It will be seen by the drawings that, owing to the great length, these machines can only be used where plenty of floor space is at command.

Sturgeon's Patent Trunk Air Compressors (See Drawing No. 9).

The machine about to be described is called a Class B.

The machine is horizontal, with one steam cylinder. The bed plate in the centre forms the water space of the air cylinders. There are two air cylinders fitted into the bed plate, which is bored out at each end to receive them. The bottoms of the cylinders are faced to form the seats of the delivery valves, which are large cheese-shaped valves. They work in the bored carrier between the two cylinders, also forming part of the bed plate.

These valves have white metal faces let in where they seat on the ends of the cylinders. The valves are kept up to their faces by spiral springs.

The opening of the valves is regulated by the hard wood buffer.

The inlet valves are in the hollow trunks at the bottom; they work in a bored carrier forming part of the trunk pistons, the air passing in through the annular space. The seats of the valves are white metal similar to the delivery valves. A guard on the upper side controls the amount of opening given to the valves. The guards also have white metal faces to deaden the blow on the carriers when open.

The two trunks are coupled by cross heads and side connecting rods. The cross heads are fixed to the trunks, the side connecting rods working through four guides. The pump pistons work alternately, one taking in air, the other compressing its charge. The piston rod is attached to the cross head at one end, and the connecting rod from the crank pin to the fore trunk. The two trunks form guides, and thus save the complication of guide bars, as well as economise space.

The trunks fit the cylinder close, and have at the lower ends Ramsbottom steel rings. The lower parts of the trunks work very close to the delivery valves, leaving scarcely any clearance space for the expansion of air, and the cross head works up to the cylinder flange through a slot at each side of the *outer* ends of the cylinders.

DOUBLE-ACTING COMPRESSORS driving by a separate engine at Ladyhore Colliery.

Steam cylinders, 14½ inches diameter by 24 inches stroke; air cylinders, 14 inches diameter by 24 inches stroke; steam pressure, 35 lbs. per square inch; vacuum, 8 lbs.; air pressure, 60 lbs. per square inch. These compressors are used to drive the following machinery underground:—Two pairs of hauling engines with 8-inch cylinders by 15 inches stroke; one 3-cylinder crab winch, 5 inches diameter by 5 inches stroke; two direct-acting pumps, each 5 inches diameter by 9 inches stroke, and the blast for three smiths' forges.

Compressed air can be used for a variety of purposes; not only to work machinery, but for sewage purposes. On Shone's Patent Pneumatic system, Sturgeon's apparatus have given the best results.

CHAPTER VI.

ENGINES FOR WORKING PUMPS.

THERE are various classes of engines used for working pumps, depending upon the quantity of water to be pumped and the circumstances of the particular case. Most of those in general use for this purpose will now be described in detail, to enable the reader to form an idea of the particular kind of engines most suitable to the case he has in hand to execute. In some cases the available space for the engine house will almost decide the question, and more especially where the pumping has to be done at an existing well surrounded by other buildings. Suitable engines for nearly all cases likely to arise in actual practice are described, making it an easy task to make a proper selection.

HORIZONTAL HIGH-PRESSURE ENGINES (Drawing No. 10).

When a moderate amount of water only is to be pumped, this class of engines are the best. They are very simple in construction, have few working parts, and can be looked after by unskilled men.

An engine equal to 12 horse-power nominal, of this class, should be of the following dimensions:—Cylinder, 12 inches diameter by 24 inches stroke; piston rod of steel, $1\frac{3}{4}$ inches diameter; piston, 4 inches deep, packed with a single ring upon the locomotive plan, the rod being collared and clipped by the upper and lower joints of the piston. The area of the steam ports should be 7·5 square inches. Variable expansion gear should be fitted, capable of cutting off at $\frac{1}{4}$ to $\frac{7}{8}$ of the stroke. Crank pin, $2\frac{3}{4}$ inches diameter by $3\frac{1}{2}$ inches long. Crank shaft, $4\frac{1}{2}$ inches diameter. Main bearing of hard gun-metal, $4\frac{1}{2}$ inches diameter by $5\frac{1}{2}$ inches long. Connecting rod, wrought iron and

42-inch centres. Fly wheel, 7 feet 6 inches diameter, and to weigh 25 cwt., square rim, turned on the periphery, with split boss, and hooped with wrought-iron rings; the wheel should be carefully balanced.

The bed plate is of the box form; the size is about 11 feet by 2 feet 4 inches. The bottom of the bed plate is planed to ensure an even bed on the stone, and is 5 inches deep and $\frac{3}{4}$-inch metal, held to the foundation by seven 1-inch diameter bolts passing through the bosses on the plates into the brickwork, and secured by plates, &c. The cylinder and jacket should be packed with felt and lagged with mahogany, secured by brass bands.

The governor may be Porter's or Tangye's patent high speed. No force pump should be attached to the engine; the boilers should be supplied by an injector or donkey pump in the boiler house, hereafter named (see p. 93).

The pressure of steam should be 40 to 50 lbs. per square inch. The speed of piston not to exceed 250 feet per minute.

The work should be the best; and when this is the case, little or no repairs would be necessary for several years. A break-down with a pumping engine in most cases is attended with serious consequences, and every possible precaution should be taken to avoid it.

Where the engines do not exceed 16 horse-power nominal, unless plenty of water can be had cheaply for condensation, high-pressure engines are the best to use; where the power required is beyond this, another class of engine may be employed.

These engines are usually made 8, 10, 12, 14, 16, 18, and 20 horse-power, the dimensions varying to suit the power. The engine (12 horse-power) described in detail, has been given as a good average size. It would take up too much space in a work of this description to give all sizes in detail.

Foundations.

The height of the centre for an engine of this size (12 horse-power) should be 2 feet 3 inches to 2 feet 6 inches from the floor of the engine house; the thickness of stone 1 foot 6 inches to 2 feet, the floor being 1 inch above the joint between the stone and brickwork. The depth of brickwork below the stone should be 4 feet, the footings three double courses. The

length of the holding-down bolts from top of stone 4 feet. The depth of the concrete 18 to 24 inches, spread 12 inches wider than the footings all round; if the bottom is not good, more concrete should be used.

In boggy places piles should be driven to the solid earth, cut off level at the tops; a platform of timber should then be laid, and on this concrete at least 24 to 30 inches thick.

The holding bolts must be provided with large plates and cottars, pulling against 4-inch stones (the full width of the foundation) at each set of bolts, or cast-iron plates may be used.

A good foundation in the first instance will always prove the most economical in the end, as the wear and tear of the engine, especially if performing heavy work, will always be materially less. The chance of a break-down is also much lessened, on account of the rigidity of the engine and consequent freedom from vibration. Where stone cannot be procured, the engine may rest upon an oak frame bedded in the brick-work.

High-Pressure Condensing Engines.

This class are either made horizontal, as above, or beam engines. For sizes, however, up to say 16- to 18-inch cylinders they may be made horizontal. In this case, *length* and not *height* in the engine room has to be considered. The most simple form is constructed in the same way as the high-pressure engine named above, the air pump being worked at the back end of the cylinder direct, the condenser surrounding the pump. The cold-water pump is worked off the cross heads. Expansion gear is used, and steam at about the same pressure as named before. Engines of this class give very good results as to fuel, but the wear and tear is necessarily more than in high-pressure engines, on account of the increased number of moving parts.

It is advisable to have a skilled attendant in charge, as the engines are more complicated in their action, and therefore require more careful attention. Particular attention is called to this, as ignorant men are too often placed in charge of such machinery.

Beam Condensing Engines.

Where the length of bed plate is an object, and where the cylinders are above 18 inches diameter, this form of engine possesses many advantages, although the first cost is much

higher than horizontal condensing engines. The cylinder is much the same as before, but fixed vertical. The beam should be formed of two wrought-iron slabs with wrought- or cast-iron distance pieces, to carry the gudgeons. The slides are worked by eccentrics from a rocking shaft, the eccentric rods being fitted with a gab end to allow the engine to be run either way. This arrangement is also very useful in starting a large engine, as, by means of a hand lever, the man can put the slide into any position and admit steam at either side of the piston. The air pump is worked half way between the cylinder and main centre, and is half the stroke of the cylinder; it is constructed as described at p. 48. The condenser usually surrounds the pump; the cold-water pump is worked off the other side of the centre near the crank. In some cases the pump for raising the water is worked direct off the beam near the crank shaft; this plan is described in detail at p. 64.

The piston speed should be slow, say 200 feet per minute. The fly wheel should be heavy and of large diameter, the weight being duly proportioned to the size of the engine.

The entablature for main centre is either carried by a column or columns, or on a girder fixed in the walls of the engine house, which should be made thicker at this part. The entablature should be box section, well ribbed on the inside.

High- and Low-Pressure Engines.

This type of engine, known originally as the "Woolf" engine, is used when the quantity of water to be pumped is large, and for sizes, say, above 20 horse-power.

They consist of two cylinders, one high-pressure and one low-pressure; after the steam is discharged from the high-pressure cylinder it enters the low-pressure cylinder, which is assisted by the air pump in the same way as a condensing engine. A high rate of expansion is used. They are very economical in working, especially as to the consumption of fuel.

They are made both in the form of "beam" and horizontal direct-acting; one of each kind will be described; the details of the various sizes of course vary very much, according to power of engine.

There has been much discussion as to the economy of this class of engine; it seems, however, now to be agreed that for

large engines, especially for pumping purposes, they give higher results than most of the usual types of rotating engines.

High- and Low-Pressure Horizontal Engines.

The most simple form, where space will allow, is to arrange, on one bed plate, the low-pressure cylinder at the back of the high-pressure cylinder, the air pump and condenser at the back again. It is a very good form of engine, but the length of the bed plate, unless there is plenty of space, precludes its general use. Except the addition of the low-pressure cylinder between the high-pressure cylinder and the air pump, it is the same kind of engine as the high-pressure and condensing engine described at p. 59.

When the required floor space cannot be had, the air pump can be fixed vertical, and either be worked off the cross head by a rocking lever, from the end of the crank shaft at the front of the engine, or between the main bearing and the fly wheel, either direct by double crank or by gear; the space at command between the bed plate and the fly wheel and other circumstances must decide this.

No. 2 Form.—The high- and low-pressure cylinder may be placed side by side and worked by the same crank shaft, the air pump being surrounded by the condenser, and placed at the back of the low-pressure cylinder; all the other details of cross head, &c., are much the same as before. One advantage of this arrangement is the space saved, which is often a very important consideration.

Any of these horizontal types of engines can be constructed and fixed at less cost than any form of vertical engine; the foundations and the cost of the engine house also are far less. All the strain is direct, and kept low; the shocks, when pumping for high lifts, are much less than with vertical engines, added to which the parts are so comparatively simple that a less skilled attendant is required to look after them, and the chances of a break-down are more remote. Some of the types of the above engines are specially described at p. 75, with working results; they have been specially selected to give data of *actual performance* spread over a long period.

High- and Low-pressure Vertical Engines.

These engines are constructed with an entablature resting either on four or six columns bolted to the bed plate. The high-pressure cylinder being placed at the front and the low-pressure next, the air pump fixed either close to it or on the outer side of the frame; a three-throw crank, running in bearings fixed on the top of entablature, is worked by the cylinders; the air pump and condenser in this case are placed below the floor line, and the cold-water pump worked off the cross head of the air pump. In some cases the low-pressure cylinder is fixed below the high-pressure under the floor line; when this is done, all the parts should be arranged to allow of easy access; no entablature is used in this case, but A frames fixed to a bed plate; the cost of the foundations is, however, much increased by this arrangement, and for several reasons this form of engine is not to be recommended unless the circumstances of the case leave but little choice.

High- and Low-pressure Beam Engines.

The compound principle was first applied to this form of engine, and where space will allow, and the first cost is not the only consideration, they are a very suitable form of pumping engine. The two cylinders are placed side by side, the high-pressure being at the end of the beam, the low-pressure close to it (or the reverse), and the air pump with its condenser below, about midway between the high-pressure cylinder and the main centre. The pump is either worked off the other end of the beam, near the crank shaft, as described at p. 64, or by means of spur gear from same, working a separate shaft driving the pump shafts; this latter arrangement must always be made when there are three pumps to be worked.

These engines give very good results, and when worked at a piston speed not exceeding 200 feet per minute, the consumption of fuel does not exceed 2 lbs. per horse-power per hour. The foundations should be heavy and the walls of the engine house substantial. The wear and tear of these engines is not great, the work is done quietly and very free from vibration. Steam of 50 to 60 lbs. per square inch is used, and the cylinders are fitted with variable expansion gear; the cylinders

should be steam jacketed, felted, and lagged with mahogany; all the pipes should be protected in the same way. In some cases super-heaters are used with much advantage.

These engines, in the author's opinion, cannot be very advantageously employed except where the quantity of water to be pumped is large. Skilled men only should be allowed to have charge of such costly machinery; all the glands want very careful packing, not only to prevent loss of steam, but to save any undue friction; the parallel motion must also have very careful supervision.

The kinds of valves used for the steam and exhaust differ: one plan is a D slide, with a grid at the back for the expansion slide to work on; or valves on the Cornish system of gun-metal double beat, or on the "Corliss" system. Engines of this kind will now be described, from which, it is hoped, a good idea may be formed by those who are not intimately acquainted with such machinery.

HIGH- AND LOW-PRESSURE COMPOUND BEAM ENGINES (Drawing No. 11), constructed by Messrs. Simpson and Co. for the Lambeth and the Chelsea Water Works Companies.

These are beam engines, and are worked coupled, with one fly wheel, the cranks being set at right angles. The high-pressure cylinders are 28 inches diameter by 5 feet $6\frac{3}{8}$ inch stroke, and the low-pressure cylinders 46 inches diameter by 8 feet stroke. One pump to each engine, $23\frac{3}{8}$ inches diameter by 6 feet 11 inches stroke.

The beams are cast iron, consisting of two cheeks, with wrought-iron gudgeons; the length between the end centres is 26 feet 6 inches, the depth at the centre is 5 feet. The main centre is 1 foot $4\frac{1}{2}$ inches diameter, the height of same from the engine-house floor being 21 feet 4 inches. The fly wheels (one to each pair of engines) are 21 feet diameter and weigh 13 tons.

The pistons of each cylinder are made solid, the high-pressure being 20 inches deep, low-pressure $12\frac{1}{2}$ inches; both are packed with Ramsbottom steel rings.

The air pumps are 30 inches diameter by 3 feet $\frac{5}{8}$ inch stroke, and are worked off the beam at the same side of the main centre as the steam cylinder; the condensers are placed

below the floor line. The cold-water pumps are 3 feet $\frac{5}{8}$ inch stroke, and are worked off the beam near the main pumps.

The valves for the cylinders are of the piston kind, and are worked by a "cam" driven by cross shaft and bevel gear. The cut off varies from one-third to two-thirds of the stroke; this system of valves answers perfectly. The cylinders are steam jacketed at the sides and bottoms.

The pumps are of the bucket-and-plunger kind, the buckets being 24 inches diameter by 6 feet 11 inches stroke; the plungers are 16½ inches diameter. The suction valves of the pump are annular, of gun-metal, working on gun-metal seats. The buckets of the pump have a single annular valve; the buckets are connected to the plungers by a rod keyed into a socket, with a collar upon same to regulate the opening of the valve. The delivery valves are of gun-metal and of the flap kind.

The connecting rods to the cranks have single ends, and work between the cheeks of the beam. The connecting rods to the pumps are double, and are placed on the *outside* of the beam, and near the end centre; they are about 24 feet long, centres to centres, and I section; the lower ends of the rods are attached to a cross head to which the plungers are keyed; the cross head is fitted with rubbing guides, which work on guide bars fixed on either side of the pumps. This is a very ingenious arrangement, as it enables the pumps to be placed near the end of the beam, the cranks working in between the double rods and clearing the cross heads.

The pressure of steam used in the cylinder is 40 lbs. per square inch. The coal used by these engines is 1·61 lb. per indicated horse-power per hour.

The author gives, on the following page, a Table (A) of a trial of engines of this kind, made by T. Hawksley, Esq., M.I.C.E., which gives very remarkable results as to water pumped and fuel consumed.

These engines have been free from break-downs; at the Lambeth Company's works six sets have been working in one house for the last thirty years, and are working now (1882) in the same steady way as they were in 1864, when the author previously saw them. He was lately informed by the superintendent of the works that no beam or connecting rod has ever been fractured, a fact that shows the careful design of the

Table A.

Detailed Report of Official Trial by Thomas Hawksley, Esq., V.-P. Inst. C.E., of Two Engines and Pumps Constructed by Simpson and Co., Engineers, Grosvenor Road, Pimlico, for the Chelsea Waterworks Company, Engines "E" and "F."

Duration of Trial from 4.15 P.M. on Friday, May 31st, to 4.18 P.M. on Saturday, June 1st, 1867.

Hour.	Number on Counter.	Head on Gauge.	Depth of Water in Well.	Total Height to which Water is lifted.	Boiler Pressure.	Barometer.	Vacuum, E Engine.	Vacuum, F Engine.	Temperature of Cold-water Cistern.	Temperature of Hot Well. E.	Temperature of Hot Well. F.	Thermometer. Engine House.	Thermometer. Yard.	Depth of Water in Cold-water Suction Well. ft. in.	Coals thrown into Boiler Furnaces during Experiment.	Lbs. raised 1 foot high per Minute.	Lbs. raised 1 foot high by 112 lbs. of Coal.	Lbs. per Horse-power per Hour.	Lbs. per Indicated Horse-power per Hour.	Horse-power exerted in Pumps.	Indicated Horse-power in Cylinder.	Fractional Horse-power, including Cold-water Feed and Air Pumps.
4.15 P.M.	77,960	185·97	32·73	218·70	38	30	26·9	27·2	65	92	91	79	72	23 8	..	..	..	..	..	..	..	..
6.15 „	79,406	186·53	32·90	219·43	41	30	26·7	26·9	65	93	92	76	65	23 9	..	7,182,000	..	..	..	218	..	..
8.15 „	81,017	184·27	32·73	217·00	41	30	27·2	27·0	64	92	91	74	60	23 7	..	7,958,000	..	..	..	241	296	55
10.15 „	82,602	184·27	32·65	216·92	41	30·1	27·3	27·0	64	92	91	74	55	23 11	..	7,784,000	..	..	..	236	..	..
12.15 A.M.	84,268	189·92	32·82	222·74	41	30·1	27·3	27·1	63	92	91	76	53	23 10	..	8,242,000	..	..	..	250	313	63
2.15 „	85,841	182·58	32·74	215·32	40·5	30	27·3	27·1	63	91	91	76	51	23 9	..	7,771,000	..	..	..	236	..	..
4.15 „	87,464	183·14	32·82	215·96	41	30	27·4	27·1	63	90	89	74	51	23 10	..	7,962,000	..	..	..	241	298	57
6.15 „	89,149	183·14	32·90	216·04	40·5	30	27·3	27·2	63	91	90	78	57	24 0	..	8,253,000	..	..	..	250	..	..
8.15 „	90,776	185·96	32·98	218·94	41	30	27·3	27·2	63	92	91	78	63	23 10	..	7,997,000	..	..	..	242	303	61
10.15 „	92,527	186·52	32·90	219·42	41	30	27·2	27·1	64	94	94	79	70	23 9	..	8,654,000	..	..	..	262	..	..
12.15 P.M.	94,341	190·47	32·98	222·45	41·5	30	27·1	26·9	65	96	94	81	74	23 11	..	9,131,000	..	..	..	277	..	..
2.15 „	96,021	189·91	32·98	222·89	42·5	30	27·1	26·9	66	94	92	76	74	24 0	..	8,474,000	..	..	..	257	312	55
4.15 „	97,666	184·26	32·81	217·07	39	30	27·2	27·0	66	93	91	78	72	..	..	8,242,000	..	..	..	250	309	59
4.18 „	97,708	..	..	..	38	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
hours 24·3	strokes 19,748	mean 186·20	mean 32·88	mean 219·08	mean 40·5	mean 30	mean 27·41		..	..	..	..	..	..	cwt. qr. lb. 105 2 11	8,141,000	111,350,000	1·99	1·61	mean 247	mean 306	mean 59

Constants.	diam.	stroke.
High-pressure Cylinder	28 in.	5 ft. 6¾ in.
Low-pressure Cylinder	46 in.	8 ft. 0 in.
Pumps (one to each Engine)	24 in.	6 ft. 11 in.
Effective Pressure in High-pressure Cylinder (mean)		27·79 lbs.

Effective Pressure in Low-pressure Cylinder (mean)	6·76 lbs.
Loss of Pressure between Pistons (mean)	0·78 lb.
Loss of Pressure from Imperfect Vacuum (mean)	1·43 lb.

REMARKS.

The working of the Engines during the whole of the trial was in every way all that could be desired, and the works have been most satisfactorily carried out by the Contractors, Messrs. Simpson and Co.

The trial was conducted under my immediate superintendence, the coals being weighed, and the accuracy of all gauges and indicators carefully tested by my assistants. The fires at the commencement and close of the observations were equally charged with coal; and every care was taken to render the experiments in every way reliable.

As will be seen by the Table, the duty performed was 111,350,000 lbs. of water lifted 1 foot high with 1 cwt. of Welsh coal, equivalent to a consumption of 1·99 lb. of coal per actual or usefully-exerted horse-power per hour, or 1·61 lb. per indicated horse-power per hour.

This remarkably high duty was obtained whilst the engines were being employed in the ordinary service of water to the Metropolis.

(Signed) T. Hawksley, C.E.

4th June, 1867.

F

sections, good quality of the castings, and workmanship. The engines at Ditton pump the water, through a 30-inch diameter main, 10½ miles, to Brixton, under a head of about 200 feet. The speed of working is about fourteen revolutions per minute of the crank shaft.

HIGH- AND LOW-PRESSURE COMPOUND BEAM ENGINES FOR LOW LIFT, working at the Lambeth Waterworks at Ditton, also by Messrs. Simpson and Co.

They were each designed to pump 420,000 gallons of water per hour 35 feet high. There are two sets of engines, each of which may be described as double engines, having two beams each, the high-pressure cylinder working one beam and the low-pressure cylinder the other, with one crank shaft and fly wheel to each set. The steam passes through a steam-jacketed receiver on its way from the high-pressure to the low-pressure cylinder. There are four pumps to each engine working on either side of the main centres.

The high-pressure cylinder is 1 foot 9 inches diameter; low-pressure ditto, 3 feet diameter by 5 feet 6 inches stroke. Pump plungers 2 feet 3 inches diameter by 4 feet stroke.

The pressure of steam is 60 lbs. per square inch cut off at one-fifth of the stroke.

The speed of piston is 240 feet per minute. The quantity of water pumped by each of the engines is 490,000 gallons per hour. The performance of these engines and their steady working is remarkable, even when running at 330 feet per minute. It may be mentioned that the quantity of water thrown by both engines under these circumstances equals about 100 tons per minute.

The description of engines given fairly represents this kind; and although in some instances the dimensions may differ, the working results as to fuel and cost of pumping will be much the same.

Table B shows the result of a trial made of these engines by Mr. John Taylor, M.I.C.E., in October, 1881. In the author's practice he has never met with such a result—the fuel consumed per indicated horse-power = 1·55 lb. Welsh coal, and the duty = 103·112 million foot-pounds per 112 lbs. of coal. The table is so clear that it does not require any further explanation.

TABLE B.

OFFICIAL TRIAL OF TWO LOW LIFT PUMPING ENGINES, constructed by SIMPSON AND COMPANY, Grosvenor Road, Pimlico, London, S.W., for the LAMBETH WATERWORKS COMPANY, DITTON. July, 1881.

These engines were each designed to pump 420,000 gallons of water per hour 35 feet high to supply the new filter beds.

They are compound beam, with the cranks set at right angles, the steam from the high-pressure cylinder passing through an intermediate receiver on its way to the low-pressure cylinder.

The cylinders and receivers are completely steam-jacketed with boiler steam.

Steam was supplied by four Cornish boilers, each 5 feet 6 inches in diameter by 27 feet long.

Welsh coal was used, and the trial was carried out by John Taylor, Esq., M.I.C.E., on September 30th, 1881.

Leading Dimensions of Engines and Pumps.

	ft.	in.
Diameter of small pistons	1	9
Diameter of large pistons	3	0
Stroke of pistons	5	6
Diameter of pump plungers	2	3
Stroke of pump plungers	4	0
Number of plunger pumps to each engine	4	

Observations Taken.

Time.	Nos. on Counters. Engine I K	Engine L M	Average Revolutions per Minute. I K	L M	Average Height of Lift.	Average Boiler Pressure.
					feet	lbs.
10.0 A.M. 6.15 P.M.	00000 10,545	00000 10,785	21·3	21·79	34·974	59·26

Time.	Average Vacuum. I K	L M	Barometer.	Average Gallons per hour. I K	L M
10.0 A.M. 6.15 P.M.	27·90	27·54	30·41	481,400	492,350

Table of Results.

Total average Actual Horse-power in Water lifted by both Engines.	Total Coal used, including 100 lbs. of Ashes.	Duty per 112 lbs. of Coal in million foot-lbs.	Mean Indicated Horse-power of both Engines.	Lbs. of Coal per Indicated Horse-power per Hour.	Lbs. of Coal per Actual Horse-power per Hour.
172·011	cwt. 27·25	103·112	238·77	1·55	2·15

The quantity of water pumped was determined by the careful measurement of a reservoir which contains 2,103,603 gallons; and at a trial made August 31st to ascertain the least time in which the reservoir could be filled, the engines pumped 2,103,603 gallons in 1 hour 40 minutes, thus exceeding their contract quantity by 50·25 per cent.

(Signed) JOHN TAYLOR, M.I.C.E.

October, 1881.

TABLE GIVING RESULTS OF TRIALS OF COMPOUND BEAM PUMPING ENGINES CONSTRUCTED BY MESSRS. SIMPSON AND CO.

	Chelsea Waterworks, Kingston.	Chelsea Waterworks, Kingston.	Berlin Waterworks, Berlin.	Fried. Krupp's Waterworks, Essen.	Bristol Waterworks, Clifton Extension.	East London Waterworks, Lea Bridge.	Lambeth Waterworks, Ditton. Filter Engines.	Chatham Waterworks, Deep-Well Pumps.
Whether Woolf or intermediate receiver engines	Woolf	Woolf	Woolf	Woolf	Receiver	Woolf	Receiver	Woolf
Date of trial	1857	1867	1869	1877	1880	1880	1881	1881
Engineer who conducted the trial	Joshua Field	T. Hawksley	H. Gill	Ruhlmann and Kley	J. Taylor	G. Seaton	J. Taylor	J. Taylor
Pressure of steam	..	40·5 lbs.	32 lbs.	41·1lbs. to 57·3lbs.	59 lbs.	56 lbs.	59·3 lbs.	
Indicated horse-power	..	306	..	136·47	235	185·647	238·77	69·57
Pump horse-power	..	247	120·66	*108·57	196·76	157	*172·011	55·45
Frictional horse-power, including air, cold water, feed, and air-charging pump	..	59	..	27·9	38·24	28·647	66·76	14·12
Efficiency of pumps $\frac{\text{P. HP.} \times 100}{\text{I. HP.}}$	..	80·719	..	79·566	83·728	84·569	72·04	79·704
Height of lift	..	219 ft.	..	378·5 ft.	190·6 ft.	195 ft.	35 ft.	
Duration of trial	24 hours	24 hours 3 min.	76 hours	137 hours	7·5 hours	12 hours	8 hours 15 min.	10 hours
Coal used	..	105 c. 2 qr. 11 lbs.	19,536 lbs.	35,409 lbs.	33·29 cwt.	41·5 cwt.	27·25 cwt.	11·9 cwt.
Description of coal	..	..	..	German	Welsh	North country screenings	Welsh	Welsh
Percentage of ash in coal	..	..	..	14·4	10	..	3·3	·64
Supposing that pump delivery equal displacement. Foot-lbs. in millions per 112 lbs. of coal	103·9	111·35	117·9	..	98·67	90	108·841	92·2
Supposing that pump delivery equal displacement. Pounds of coal per pump horse-power per hour	..	1·99	1·88	..	2·32	2·46	2·056	2·4
Calculated from the actual delivery of pumps. Foot-lbs. in millions per 112 lbs. of coal	..	..	112·5	93·6	..	..	103·112	
Calculated from the actual delivery of pumps. Pounds of coal per pump horse-power per hour	..	..	1·97	2·37	..	..	2·15	
Including ash.—Pounds of coal per indicated horse-power per hour	..	1·61	..	1·89	1·94	2·08	1·55	1·92
Excluding ash.—Ditto ditto ditto	..	..	..	1·62	1·75	..	1·50	1·91

* This horse-power is calculated from the measured quantity delivered.

High- and Low-Pressure Pumping Beam Engines at Clifton, near Bristol, made and erected by Messrs. Simpson and Co. (Drawing No. 12).

The pumping machinery consists of two pairs of compound beam engines of the intermediate receiver type, actuating four double-acting pumps of the kind known as "bucket and plunger."

Each pair comprises two complete single engines, viz. one high- and one low-pressure engine, coupled together by means of cranks at right angles on one fly-wheel shaft.

Each single engine, with its pump, is complete in itself, and can be worked independently, but they are coupled in pairs in ordinary work, so as to obtain the maximum uniformity of rotative effect in the engine with a high rate of expansion, and likewise to regulate the relative action of the pumps in order to obtain the most uniform flow of water in the suction and delivery mains.

The high-pressure cylinders are $25\frac{1}{2}$ inches, and the low-pressure 38 inches diameter, both having a stroke of 5 feet 6 inches. They are each connected to the ends of their respective beams by a simple single-link parallel motion, the extreme opposite ends of the beams being connected to the cranks which govern the relative movement of each pair of steam pistons and pump buckets. The distance between the cylinders and connecting-rod gudgeons on the beams is 18 feet $10\frac{13}{16}$ inches.

The cylinders are completely enveloped with a steam space, which is so connected to the boilers as practically to form a part of the same. The lowest part of the steam space of each cylinder is considerably above the tops of the boilers, and all the steam flow and return connections are arranged with a continuous fall, without water pockets, so as to promote an active circulation of steam at the temperature of the boilers.

The whole of the external surface of the cylinders is coated with non-conducting composition, and covered on the sides with polished mahogany lagging, and on the tops with bright moulded cast-iron covers.

The distribution of the steam is effected by slide valves with Meyer's expansion gear. Each end of all the cylinders has its own set of valves, which can be easily and independently adjusted to regulate the various points of the distribution; and

the period of steam admission into both high- and low-pressure cylinders can be varied from 0 to ·75 of the stroke while the engines are working.

The intermediate receivers are also each enveloped by a steam space, covered with non-conducting composition, and lagged similar to the cylinders. In order to render them more efficient as superheaters, the steam on its passage through each is conducted past a narrow annular space, formed by an inside cylindrical casing, and the inner walls of the space filled with steam at a high temperature.

The high-pressure cylinder can be shut off, and the receiver in each case supplied with steam direct from the boilers, when it is desired to work the low-pressure engine by itself, and *vice versâ.*

The steam is exhausted from the low-pressure cylinders into surface condensers placed on the main leading from the supply reservoir to the suction standpipes. The surface condensers are cylindrical, filled with gun-metal tubes, through which the exhaust steam passes, the water from the reservoir flowing to the standpipes outside the tubes.

The air pumps are placed close to the condensers, but at a lower level, so as to thoroughly drain the same, and are single-acting bucket pumps, worked direct from the beams of the low-pressure engines.

The condensed water is discharged into a cistern, from which it is drawn by the feed pumps, and again forced back into the boilers. By this arrangement the quantity of water required for working the engines is reduced to a minimum, thereby effecting a great saving, the water supplied to the main pumps having been filtered and already raised to a great height, and being therefore very valuable.

The main pumps are $17\frac{1}{2}$ inches diameter by 4 feet $7\frac{5}{16}$ inches stroke. They are divided in pairs, corresponding to the high- and low-pressure cylinders of each pair of engines, and are driven from the crank-shaft ends of the main working beams.

Each pair of pumps are fixed on one suction pipe, and draw their water from single open-topped standpipes placed in the pump wells, both of which receive their supply through one long main from a reservoir some distance away.

There are two delivery air vessels, one for each pair of pumps, the outlets of which are connected into one main delivery pipe.

The pump valves are of the double-ring description, with four beats of sufficient diameter and area to admit of the pumps being worked with the greatest economy, at a speed of twenty double strokes per minute.

Table C shows the result of a trial of two compound engines, also made by Mr. John Taylor, M.I.C.E. The table speaks for itself, and needs no further comment.

TABLE C.

OFFICIAL TRIAL OF TWO ROTATIVE COMPOUND BEAM ENGINES, CONSTRUCTED BY SIMPSON AND COMPANY, GROSVENOR ROAD, PIMLICO, LONDON, S.W., FOR THE CLIFTON EXTENSION OF THE BRISTOL WATERWORKS.

These engines were designed to pump together 180,000 gallons of water per hour, 175 feet high.

They are on the system of E. A. Cowper, Esq., with an intermediate receiver, through which the steam passes on its way from the high-pressure to the low-pressure cylinder.

The cylinders are completely steam-jacketed with boiler steam, and the delivery from the pumps passes through a surface condenser. Steam was obtained from two Lancashire boilers, 7 feet in diameter by 30 feet long.

Welsh coal was used, and the trial was carried out by John Taylor, Esq., C.E.

Leading Dimensions of Engines and Pumps.

	ft.	in.
Diameter of piston of small cylinder	2	1½
Diameter of piston of large cylinder	3	2
Stroke of pistons	5	6
Diameter of barrel of bucket-and-plunger pumps (two to each)	1	5½
Stroke of pumps	4	7½

Observations taken.

Date of Trial.	Nos. of Counters.		Average Revolutions per Minute.		Average Height of Lift from Mercurial Gauge.	Average Boiler Pressure.
April 13th, 1880.	No. 3.	No. 4.	No. 3.	No. 4.		
7.51 A.M.	405,240	408,500				
1.27 P.M.	411,666	415,030	19·12	19·43	196·86	60·0
2.27 „	412,518	415,030	14·2	..	176·00	57·0
4. 0 „	414,352	416,804	19·72	19·07	196·97	60·1

Date of Trial.	Average Vacuum.		Barometer.	Average Gallons of Water delivered per hour.	Remarks.
April 13th, 1880.	No. 3.	No. 4.			Fires had to be cleaned out at 1.27 P.M., and No. 4 engine was stopped for 1 hour, as steam ran down.
7.51 A.M.					
1.27 P.M.	27·5	27·7	..	222,796	
2.27 „	27·4	..	29·75	82,047	
4. 0 „	27·7	27·7	..	224,161	

Tables of Results.

Total average Actual Horse-power in Water, lifted by each Engine.	Total Coals used, including 3·29 cwt. of Ashes.	Duty per 112 lbs. of Coal in millions of foot-lbs.	Mean Indicated Horse-power of each Engine from Diagrams.	Lbs. of Coal per Indicated Horse-power per hour.	Lbs. of Coal per Actual Horse-power per hour.	Cwts. of Coal (including Ashes) per hour taken on the total Actual Horse-power.
98·38	33·29	98·67	117·5	1·94	2·32	4·06

April, 1880. (Signed) JOHN TAYLOR, C.E.

NOTE.—In the above table the ashes, amounting to nearly 10 per cent. of the total coal used, are included; if they were deducted the results would be as under:—

Total average Actual Horse-power in Water lifted by each Engine.	Total Coals used in cwts. (Ashes deducted).	Duty per 112 lbs. of Coal in millions of foot-lbs.	Mean Indicated Horse-power of each Engine from Diagrams.	Lbs. of Coal per Indicated Horse-power per hour.	Lbs. of Coal per Actual Horse-power per hour.	Cwts. of Coal (deducting Ashes) per hour taken on the total Actual Horse-power.
98·38	30·00	109·49	117·5	1·75	2·09	3·68

HIGH AND LOW PRESSURE COMPOUND BEAM ENGINES FOR WATERWORKS PUMPING.—Constructed by Messrs. Easton and Anderson (Drawing No. 13).

The following engines were manufactured and erected by Messrs. Easton and Anderson. A short description is given of each, with actual data of working results. It will enable the reader to form an idea of the dimensions, &c., of engines suitable for the performance of a required amount of work. They are all made on much the same plan, but differ as to details. The leading dimensions of several engines by this firm will now be given, with actual working results, both as to water pumped and fuel consumed.

1. *Brighton Waterworks.*—One of the engines is constructed as follows:—

It is a double cylinder, compound, condensing beam engine, with two deep-well lift pumps under the beam, one on each side of the centre of the beam, one high lift bucket and plunger pump under the beam on the crank side, and a similar pump placed under the outer end of the fly-wheel shaft, and worked by a crank on same. Cylinders 28 inches diameter by 5 feet 4¾ inches stroke, and 46 inches diameter by 8 feet stroke. The number of revolutions per minute = 16. Deep-well pumps,

each, 33½ inches diameter by 2 feet 6 inches stroke, with a lift of 129 feet net. One bucket and plunger pump, under beam, for middle service, 24 inches and 17 inches diameter, by 3 feet 6 inches stroke; 92 feet lift net. One similar pump, 4 feet stroke, for high service, with a lift of 166 feet net. Engine indicates 250 to 300 horse-power. Efficiency 75 to 80 per cent.

Portsmouth Waterworks.—One of the engines is as follows:—

It is a double cylinder, steam-jacketed, compound, condensing beam engine, working one double-acting pump under the beam, on the crank side. Cylinder 27 inches diameter by 3 feet 9 inches stroke, and 38 inches by 6 feet stroke. Pump 23 inches diameter by 3 feet stroke. Number of revolutions per minute = 22, indicating 140 horse-power. Total head on pumps = 160 feet. Work done = 2376 gallons of water lifted per minute.

Lambeth Waterworks.—One set of the engines is as follows:—

Two single cylinder, steam-jacketed, beam engines, with surface condenser, acting on cranks at right angles on the same fly-wheel shaft, form together a compound engine. Each engine works one bucket and plunger pump under the beam on cylinder side. Cylinders 22½ inches diameter and 45 inches diameter by 5 feet 6 inches stroke. Pumps 22½ inches and 16 inches diameter by 2 feet 9 inches stroke. Number of revolutions per minute = 22, indicating 163 horse-power. Total head on pumps = 226 feet. Work done = 2083 gallons of water lifted per minute. Efficiency 89 to 91 per cent.

Antwerp Waterworks.—There are four double cylinder, steam-jacketed, compound, condensing beam engines, arranged in two pairs, each pair being connected by working cranks at right angles at the end of a fly-wheel shaft common to both. Each of the four engines works one bucket and plunger pump under the beam on cylinder side. Cylinders 18½ inches diameter by 3 feet 8 inches stroke, and 30 inches diameter by 5 feet 6 inches stroke. Pump 22½ inches and 16 inches diameter by 2 feet 9 inches stroke. Number of revolutions per minute = 22, indicating 100 horse-power. Total head on pumps = 280 feet. Work done = 1042 gallons of water lifted per minute. Efficiency nearly 90 per cent.

Ramsgate Waterworks.—A double cylinder, steam-jacketed, compound, condensing beam engine. The fly-wheel shaft carries spur gearing to drive two sets of three-throw pumps, one wheel in each set of gearing being made to slide in or out of gear, if required. Cylinders 15 inches diameter by 3 feet 1½ inch stroke, and 25 inches diameter by 4 feet 6 inches stroke. Number of revolutions per minute = 30, indicating 75 horse-power. First set of pumps is 14 inches diameter by 2 feet stroke; second set of pumps is 11¾ inches diameter by 2 feet stroke. Each set makes 13 revolutions per minute. Total head on pumps = 200 feet, and at times more. Work done by first set of pumps = 516 gallons lifted per minute; work done by second set of pumps = 360 gallons lifted per minute.

Sevenoaks Waterworks.—A similar engine to the last, working one set of three-throw pumps only. Cylinders 12½ inches diameter by 2 feet stroke, and 20 inches diameter by 3 feet stroke. Number of revolutions per minute = 40, indicating about 45 horse-power. Pumps 11¾ inches diameter by 2 feet stroke, making 12 revolutions per minute. Net head to which water is lifted = 275 feet. Work done = 338 gallons lifted per minute.

It will be observed that all the engines named give very high results as to economy in fuel; they are fine machines, perform their duty in the most admirable manner, and reflect the highest credit upon Messrs. Easton and Anderson.

The author believes the firm were one of the first to apply the compressed system to waterworks pumping, and for upwards of thirty years have successfully carried out many large works of this kind, only a few examples of which could be described in the space at disposal.

Horizontal Direct Acting Pumping Engines, constructed by Messrs. Hick, Hargraves & Co., Bolton. (Drawing No. 14).

These engines have cranks at right angles arranged to be worked either together or separately. The steam cylinders, which are 24 inches diameter by 4 feet stroke, are connected with the crank shaft pedestals by "Corliss" frames, which allow of a maximum strength with a minimum of weight, the material being disposed in the direct line of the strain, and not, as in the old form of frame, at some distance below it. The pumps lie behind the cylinders, and

are bolted down to a sole plate, which extends under the cylinders also. The valves of the steam cylinders are common slide valves, having "Meyer" cut-off valves working on their backs, which can be made to approach, or to recede from one another by means of right and left handed screws formed on the valve rods, thus increasing or diminishing the lap, and cutting off the steam earlier or later in the stroke. The pumps are double acting, and are 9 inches diameter by 4 feet stroke; the valves are of gun-metal, working on gun-metal seats. The pumps draw water from a well 13 feet deep, and deliver it at a height of 240 feet through 3500 yards of 9 inch and 8 inch pipes. They are calculated to deliver 40,000 gallons per hour when running at their nominal speed of 22 revolutions per minute; this corresponds to an indicated horse-power of 140.

These engines were made in 1874, and are for supplying water to the hydraulic establishment at the Royal Arsenal, Woolwich. They are a good example of this type of pumping engine; well designed, and suited for the work to be done.

THE DIFFERENTIAL PUMPING ENGINE (Drawings Nos. 15 to 18).

DAVEY'S PATENT PUMPING ENGINES.—These engines are constructed by Messrs. Hathorn, Davey, and Co. of Leeds, and are on an entirely different system to the ordinary type of pumping engines. A description is given in detail, describing the system, and also data of actual working results. The engines are specially adapted for deep-well and mine pumping, and for the heavier class of work, and have been adopted largely for the water supply of towns.

The differential engine exists in two distinct types, viz. the single cylinder and the compound engine; the latter, admitting of being worked with high degrees of expansion, is capable of realising the greatest economy in fuel.

The differential gear is equally applicable to vertical or horizontal engines, the former type being usually adopted for water works or sewage pumping engines; while for mines, where it is often impracticable to place cylinders vertically above the shaft, the latter, working either from the surface by means of quadrants, or underground with the well-known double-ram pump, is usually employed.

The chief peculiarity in the invention is the simple manner in which the engine is made perfectly safe in working under

all conditions of load, automatically varying its supply of steam in proportion as the load on the engine increases or decreases, the distribution of steam being such that the pumping is performed without shock.

The distribution of steam is effected by coupling the motion of the engine with that of a piston having a uniform velocity. The engine is made to cut off steam by its motion, whilst the uniformly moving subsidiary piston is employed in admitting it. As long as the resistance to the engine is sufficient to prevent its motion becoming relatively equal to that of the subsidiary piston, steam is admitted up to a fixed point of cut off; but should a loss of resistance or a superior pressure of steam cause the engine to acquire a speed relatively greater than the speed of the subsidiary piston, then the motion of the steam valve would be reversed earlier, and the supply of steam would be adjusted to the altered conditions. The *modus operandi* is best illustrated by the following diagrams.

The action of the differential valve gear is illustrated in the diagrams, Drawing No. 19. These diagrams are not drawn to scale, but are intended to show clearly the action of the gear; whilst Drawing No. 20 shows a practical example of its application to a compound engine. The main slide valve G is actuated by the piston rod through a lever H working on a fixed centre, which reduces the motion to the required extent and reverses its direction. The valve spindle is not coupled direct to this lever, but to an intermediate lever L, which is jointed to the first lever H at one end; the other end M is jointed to the piston rod of a small subsidiary steam cylinder J, which has a motion independent of the engine cylinder; its slide valve I, being actuated by a third lever N, coupled at one end to the intermediate lever L, and moving on a fixed centre P at the other end. The motion of the piston in the subsidiary cylinder J is controlled by a cataract cylinder K on the same piston rod, by which the motion of this piston is made uniform throughout the stroke; and the regulating plug Q can be adjusted to give any desired time for the stroke.

The intermediate lever L, has not any fixed centre of motion, its outer end M being jointed to the piston rod of the subsidiary cylinder J; the main valve G consequently receives a differential motion compounded of the separate motions given to the two ends of the lever L.

If this lever had a fixed centre of motion at the outer end M, the steam would be cut off in the engine cylinder at a constant point in each stroke, on the closing of the slide valve by the motion derived from the engine piston rod; but inasmuch as the centre of motion at the outer end M of the lever shifts in the opposite direction with the movement of the subsidiary piston J, the position of the cut-off point is shifted, and depends upon the position of the subsidiary piston at the moment when the slide valve closes. At the beginning of the engine stroke, the subsidiary piston is moving in the same direction as the engine piston, as shown by the arrows; and in the instance of a light load, as illustrated, the engine piston having less resistance to encounter, moves off at a higher speed, and sooner overtakes the subsidiary piston, moving at a constant speed under the control of the cataract; the closing of the main valve G is consequently accelerated, causing an earlier cut-off. But with a heavy load, the engine piston encountering greater resistance, moves off more slowly, and the subsidiary piston has time consequently to advance further in its stroke before it is overtaken, thus retarding the closing of the main valve G, and causing it to cut off later. At the end of the engine stroke, the relative positions become reversed, in readiness for the commencement of the return stroke.

The subsidiary piston J, Drawing No. 20, being made to move at a uniform velocity by means of the cataract K, the cut-off consequently takes place at the same point in each stroke, so long as the engine continues to work at a uniform speed; but if the speed of the engine becomes changed, in consequence of a variation in the load—if, for instance, the load be reduced, causing the engine to make its stroke quicker—the subsidiary piston has not time to advance so far in its stroke before the cut-off takes place, and the cut-off is therefore effected sooner. On the contrary, if the load be increased, causing the engine stroke to be slower, the additional time allows the subsidiary piston to advance further before the cut-off takes place, and the cut-off is consequently later.

From the foregoing description of the valve gear, it will be understood that every erratic motion of the engine alters the relative position of the valves with respect to the main piston, and in that way the engine checks itself.

So perfect is the action of this gear, that when properly

adjusted, the full load may be thrown suddenly off the engine without any injury resulting. The effect of a sudden loss of load is to reverse the action of the valves, and *to throw the steam against the motion of the piston, stopping it before the end of the stroke.* Many instances of this have occurred in practice when a pump rod has broken, a pump valve has failed, or a pipe has burst.

At the St. Helen's Waterworks the mains burst without causing the slightest damage to the differential engine.

As another instance of the steadiness of the engine with unequal loads, it may be mentioned that the differential engine has often been worked with the pumps on one end only, so that the whole power of the engine was exerted on one side of the pistons only, and none whatever exerted on the other; yet the engine moved along so steadily that the action could not be noticed unless one's attention was called to it, and the engine was actually run this way for some days to full number of strokes. Now the throttle valve had to be open, and in the same position as if both pumps were on, and the Davey motion had to do all the regulating.

For waterworks pumping at St. Helen's, cost of fuel per 1000 gallons of water raised 100 feet high, ·1121*d.* Taking the total cost of pumping, fuel, wages, stores, repairs, equal ·29*d.* At Yarlside Colliery the total cost of pumping 1000 gallons 100 feet high = ¼*d.*, taking all expenses, and allowing 10 per cent. interest on capital, cost of coal being 11*s.* 3*d.* per ton. At the Staffordshire Potteries Waterworks a compound differential engine now does the work formerly done by an 80-inch Cornish engine, with one-third less fuel. The duty of the differential engine is 60 millions on the slack coal of the district, equal to 90 millions on Welsh steam coal.

The following comparison of the two systems, Cornish and compound differential, are taken from actual tests in practice:—

	Initial Pressure.	Rates of Expansion.	Average Pressure.	Maximum Piston Velocity per Minute.	Relative Strains on Engine.	Effective Piston Speed.
			lb.	feet.		
Cornish ..	31	3	16	600	1·8	100
„ ..	45	4·5	19	500	2·26	80
Differential	43	6¼	13	228	1·4	168
„	80	8	24	220	1·37	150

The table on p. 80 gives the actual working results of one of these engines from a trial made, and the following one gives an idea of the power, &c., of various sizes, now in use.

DIFFERENTIAL PUMPING ENGINES.

No.	Horse-power.	No. of Gallons Raised per Hour.	Height to which Water is Raised.	No.	Horse-power.	No. of Gallons Raised per Hour.	Height to which Water is Raised.
1	585	120,000	668	46	112	19,800	600
2	585	120,000	720	47	112	48,000	180
3	476	..	..	48	112	48,000	180
4	462	..	..	49	112	..	..
5	433	..	..	50	106	15,600	855
6	406	120,000	435	51	95	15,000	400
7	394	100,000	600	52	95	15,000	400
8	340	152,174	200	53	92	40,000	240
9	330	84,000	600	54	89	..	..
10	312	42,000	910	55	86	300,000	20
11	312	42,000	910	56	85	..	..
12	304	37,200	200	57	80	72,000	80
13	300	..	..	58	78	24,000	300
14	254	72,000	360	59	78	24,000	240
15	254	..	600	60	78	18,000	480
16	254	60,000	345	61	78	..	..
17	254	30,000	920	62	78	..	..
18	254	..	..	63	71·3	..	..
19	254	..	..	64	71·3	..	..
20	254	..	..	65	71·3	115,800	70
21	235	37,200	1,200	66	71	..	870
22	235	37,200	1,200	67	70	..	300
23	230	..	..	68	66	39,000	220
24	230	..	..	69	64	..	..
25	230	..	..	70	62	62,500	190
26	223	..	1,500	71	62	62,500	190
27	217	46,800	600	71A	60	39,000	240
28	200	..	..	71B	60	39,000	240
29	198	24,000	1,100	72	57	13,440	555
30	198	30,000	450	73	51	..	..
31	193	..	..	74	50	11,400	350
32	193	..	..	75	50	11,400	350
33	193	..	..	76	48	..	..
34	193	..	..	77	44	12,000	260
35	183	90,000	420	78	44	13,200	262
36	168	60,000	500	79	41	420	750
37	159	60,000	323	80	41	50,000	100
38	154	48,000	600	81	41	12,000	290
39	154	37,600	410	82	41	6,000	480
40	140	24,000	720	83	41	..	..
41	135	7,200	600	84	35	18,000	100
42	125	36,000	390	85	35	6,600	465
43	125	..	..	86	34	12,000	480
44	115	54,000	1,220	87	30	30,000	151
45	115	15,000	600				

THE FOLLOWING IS THE RESULT OF A TRIAL OF A COMPOUND DIFFERENTIAL ENGINE AT THE EAST HETTON COLLIERY.

Mean stroke of engine	7 ft. 2¼ in.
Mean number of double strokes per minute	8
Mean piston speed in feet per minute	115 ft.
Mean pressure of steam in engine room	62 lbs.
Mean vacuum in condenser	11¾ „
Mean effective pressures in cylinders—	
Front of high-pressure cylinder	44·79 lbs.
Back of „ „	48·52 „
Front of low-pressure „	9·03 „
Back of „ „	10·37 „
Indicated horse-power developed—	
In high-pressure cylinder	146·42 h.-p.
In low-pressure „	108·05 „
Total	254·47 „
Condensing water—	
Quantity of water discharged per minute over tumbling bay	1,877 lbs.
Mean temperature of ditto	103·5°
Mean temperature of injection water	55°
Rise of temperature of the water in the condenser	48·5°
Pounds-degrees of heat discharged from the condenser per minute	91,034 units.
Ditto per horse-power	357·7 „
Consumption of steam per horse-power per hour	22 lbs.
Equivalent duty per 112 lbs. of coal, assuming each lb. of coal to evaporate 9 lbs. of water	90,720,000
Equivalent duty per 112 lbs. of coal, assuming each lb. of coal to evaporate 10 lbs. of water	100,800,000
Effective work performed in pumps	198·6 h.-p.
Effective work in percentage of indicated horse-power	78·05 %

Duty 100 millions on an evaporation of 10 lbs. of water per lb. of coal.

These engines work very steadily, and, as will be seen, also economically; they are simple in construction, the wear and tear is small, and they bear favourable comparison with the best types of pumping engines.

The differential valve gear can be applied to Cornish and compound engines, and where the engines are subjected to violent strains from the breaking of the pump rods, as in deep well or mine pumping, the gear controls the engine immediately, and prevents further accidents to the machinery.

CHAPTER VII.

CORNISH ENGINES.

It is unnecessary to enter into any historical account of the first use of the Cornish engine; it may, however, be stated that the first single-acting engine, in its present form, for pumping water for the supply of London was introduced by Mr. Wickstead in 1837, at the East London Waterworks, Old Ford, who purchased one in Cornwall, having a 90-inch cylinder by 10 feet stroke. It is working up to the present time. This class of engines is extensively used by the large London water companies, and it is contended by those who advocate their use, that they still are the most economical pumping engines; the author intends hereafter to give some working results, having been favoured by some of the engineers to the water companies with the same.

The economy of the Cornish engine is more apparent in countries where coal is very dear. It must always be borne in mind, in calculating the cost of pumping water, that all expenses must be taken, including interest upon the original cost of the engine and foundations, repairs and sinking fund, fuel, oil, labour, supervision, &c.

The author describes, hereafter, two or three good examples from actual practice; they are powerful engines, and the working results given are an average taken over one year. The accuracy of the data may be relied on.

There are two types of these engines in use at waterworks, although there are several that differ in slight details. The beam and the direct-acting or "Bull" engine are the only ones that need be noticed. The Cornish beam engine is single acting, the steam acting on the top side of the piston. At the other end of the beam, the pump with its pole plunger and

counterbalance are worked; the weight of these is sufficient to overcome the dead load of the column of water to be lifted, including friction. No fly wheel or crank shaft is required. The air pump is worked in the same way as the ordinary beam engines.

The valve motion of the cylinder is worked by tappets, and consists of double-beat valves described at page 10, except that the faces are conical; a very ingenious contrivance called a "cataract" controls the opening and closing of the valves. A high rate of expansion is used, in some instances the steam is cut off at $\frac{1}{4}$ of the stroke of the piston. The pressure of steam is about 50 to 60 lbs. per square inch, although in some cases steam of a lower pressure is used; it is not, however, so economical in working as high-pressure steam cut off at an early part of the stroke.

The pumps in nearly all these cases are of the plunger kind and single acting. To save fracture to the engine and pump, in case of missing the stroke, at each end of the beam two bars of wrought iron are fixed, which rest upon strong timbers. At the end of each stroke there is a short interval of time, which allows the valves to close.

The cylinders are steam jacketed, packed with felt, and lagged with mahogany on the outside in the usual way; steam is also admitted to the stuffing boxes, to prevent air being drawn into the cylinder in case of any leakage in the packing.

This class of engine can only be successfully applied upon a large scale; they are very costly, somewhat cumbersome, and the valve motion rather complicated. In some places they are still the favourite engine, and certainly give very high results as to economy of fuel. The foundations and the engine house are of necessity rather costly. The following is a description of some of the largest of this class made upon a modern principle:—

At the Southwark and Vauxhall Water Company's works at Hampton there are a fine pair of engines, and although not the largest of their class, they are very good examples of this kind of engine. There are two engines, one on each side of the house (Drawing No. 21). The cylinders are 80 inches diameter by 10 feet stroke, piston rods 7 inches diameter, steam pipes 11 inches diameter.

The cylinders are steam jacketed, the covers also, and the

bodies of the cylinders are coated with composition and lagged with corrugated iron on the outside. There are four valves in connection with the cylinder, all on the double-beat plan, and made of gun-metal. At the top of the cylinder are three steam valves. No. 1 is on the steam pipe, for starting the engine, and worked by hand; this is called the governor, and regulates the amount of steam to be admitted. No. 2, top, is a steam inlet, and is opened by the "cataract"; the amount of opening is adjusted by a slide on the plug rod; this also regulates the power of cutting off steam. No. 3 is the exhaust valve (at the bottom of the cylinder), worked in the same way as the last, and under control of the "cataract." No. 4 is the equilibrium valve, opened by the working rod during the "up" stroke.

The stroke commences by opening the exhaust valve; this ensures the cylinder being clear on the under side of the piston; the steam valve is then quickly opened by the cataract; the steam rushing in on the top side forces down the piston; the valve is closed by the plug rod, according to the required grade of expansion; the rest of the stroke is made by the expansion of the steam and the momentum of the parts in motion; the exhaust valve is closed before the piston arrives at the bottom of the cylinder, and the equilibrium valve is opened, connecting the top and bottom of the cylinder. The loaded plunger of the pump at the other end of the beam brings the piston to the top, and forces the steam from the top to the under side of the piston, the equilibrium valve being closed just before the finish of the stroke. The beam is cast iron, with two cheeks, 6 feet deep at the centre; the weight is about 17 tons. The entablature on which the main centre is carried is of cast iron, built in the side walls, and supported by four columns. The main gudgeon is 18 inches diameter.

The pressure of steam used is 40 lbs. per square inch, cut off at two-thirds of the stroke; speed of piston 8·5 strokes per minute; velocity in feet per minute, 170; vacuum = 28 inches.

The pumps are double acting, with barrels 24¾ inches diameter by 10-foot stroke; the head of water = 220 feet. The quantity of water pumped = 200 gallons per stroke, or take the up and down stroke = nearly 400 gallons, and at 8 strokes per minute = 3200 gallons. The pumps have solid pistons, and are attached to pump rods 6½ inches diameter. The counter-

balances are cast iron, loaded, and weigh about 23 tons. The valves are of the Cornish kind, the suction valves having 4 beats, and the delivery ditto 2; the faces are flat, and made of gun-metal. The suction valves have larger area than the delivery, to allow of the water passing rapidly into the pump barrel on the up stroke of the plungers.

The air pumps are 42 inches diameter by 5-foot stroke; they have condensers of the usual kind. The vacuum = 28½ inches. The cold-water pumps are worked off the counterbalances of the main pumps.

The duty performed by these engines is equal to 80,000 lbs. raised 1 foot high, by each 112 lbs. of Welsh coal, equal to about 2¾ lbs. per horse-power per hour. The "slip" of the pumps does not exceed 2 per cent. The average effective horsepower = 209.

In these engines the water is raised by the fall of the counterbalances attached to the pump rods at the back end of the beams, the steam in the cylinders being admitted, as before stated, at the top side of the pistons, the lower side being open to the exhaust. When the piston is at the bottom of the stroke, the plunger is ready to descend; when it has made the full stroke, it rests sufficient time for the valves to close. The "up" strokes of the plungers are made very rapidly, due to the sudden admission of steam at the top of the pistons.

The lift of the suction valves does not exceed 2 inches; this, however, gives full area for the passage of the water into the pump. The diameter of the delivery main = 30 inches.

The air vessel is cast iron, 4 feet diameter by 18 feet high; two small pumps worked by the engines are employed to keep up the supply of air.

This company have the largest Cornish beam engine used for waterworks purposes; the cylinder is 112 inches diameter by 10-foot stroke, and works at the rate of 7 strokes per minute. The velocity of piston = 138 feet per minute, pressure of steam = 35 lbs., and the average throughout the stroke = 24·48 lbs., vacuum = 28 inches. The pump plunger is 50 inches diameter. The average head of water pumped is about 170 feet. The number of gallons per stroke = 820, average effective horse-power 292. Air pump 56 inches diameter by 5-foot stroke. Beam is double, 8 feet 9 inches deep at the centre, of cast iron, by 31 feet 6 inches long, and weighs about 40 tons. The main

centre is 18 inches diameter, piston rod 11 inches diameter. The valve motion is the same as before described, and the general design is also much the same.

Cornish Direct-acting or "Bull" Engines (Drawing No. 22).—Where space is an object, engines of this class may be employed. The cylinder is fixed upon a powerful frame, fitted with valve motion as before, and the weighted plunger pole immediately under same. To make the matter clear, the author gives the following description of three engines working at Hampton:—

There are three engines in one house; the cylinders are two 66 inches and one 70 inches diameter, by 10 feet stroke. Number of strokes per minute equal 7; velocity of piston per minute = 140 feet; steam 40 lbs. per square inch; cut off at half-stroke. The cylinders are steam-jacketed, the covers also. The piston rods are 7½ inches diameter; two of the pumps have plungers 39 inches diameter by 10 feet stroke, and one 42 inches diameter by 10 feet stroke. The weight of the ram piston and rod = in two of the engines 30 tons, and one = 35 tons. The quantity of water pumped by each pump = 516, 516, and 600 gallons per stroke; lift of water 135 feet. The pumps are single acting, and have valves of the same kind as described before at pp. 10 and 82. The air pumps are 20 inches and 24 inches diameter by 5 feet stroke; the vacuum made = 27 inches.

The duty of these engines = 60 to 65 millions of lbs. raised 1 foot high by 112 lbs. of Welsh coals at 25*s*. per ton. The average effective horse-power is 136, 143, and 170. The air pumps and cold water pumps are worked by rocking levers or half beams fixed under the cylinders, the fulcrums being at the wall, and attached to the piston rods at the other end by side links; the guides for the air pumps, &c., are of the usual type.

These engines are very compact, and give good results; but the expansion cannot be carried so far as in the beam engines. The cost of the brickwork for the house and foundations is considerably less, and the first cost of the engines also. This fact, combined with the small space they occupy, will often settle the question as to the particular kind of Cornish engine to be employed. The valve motions are the same as the beam engines before described. There is a pause, as in the other engines, at the end of each down stroke of the pump plungers, to allow the valves to close; the "up" stroke is made rapidly

and in all other respects the action of the engines is the same as the "beams." The head of water is 35 feet. The diameter of the delivery main = 36 inches.

The water is pumped from the settling reservoirs into two air vessels of cast iron, 4 feet 6 inches diameter by 16 feet high, and thence into a standpipe.

These engines have been in use since 1852, and the author believes were the first of this kind fixed in London for waterworks purposes. Considering the number of years they have been at work (about thirty years), and that expansion cannot be carried so far as in the beam engines, they are very economical and give good working results. The repairs during the period have been very small.

Cost of Pumping, Fuel, &c., in Cornish Engines.

The average coals consumed per million gallons at one of the large waterworks, pumping by Cornish Bull engines = 1 ton 0 cwt. 1 qr. Coals consumed per million foot-lbs. of water, average for twelve months = 1·63 lb. Coals consumed per horse-power per hour = 2·46 lbs. Oil and tallow consumed for twelve months, per million gallons of water pumped: oil, ·14 pint, and tallow ·6 lb.; and per million foot lbs., oil = ·00008 pint, tallow = ·00066 lb. Cost per million gallons, including coals, oil, and tallow, 1*l.* 1*s.* 9*d.* Cost per million foot-lbs., ·152*d.* Cost per million gallons, for wages and engine repairs (only), 9*s.* 5¾*d.*; and per million foot lbs., ·0671*d.* Cost per million gallons, for coals, oil, tallow, waste, wages, and engine repairs, 1*l.* 11*s.* 3½*d.*; and per million foot-lbs., ·218*d.*

Horse-power employed to raise one million gallons of water one foot high = ·2396.

The above is an average taken for twelve months, from the returns of one of the largest London water companies, and is very valuable testimony as to the actual results of working upon a large scale. For smaller engine power and a less number of engines such high results must not be expected.

Foundations.

It need hardly be said that the foundations of the engines must be solid, and well able to resist the heavy shocks they have to sustain. In places where the ground is marshy, piles must be

driven into the solid earth, and a timber foundation formed on top of same, on which a good concrete bed in Portland cement should be laid. The brickwork is built upon this, and heavy base stones at the top, to take the cylinders, &c. Granite is the best material, but rather costly; in small engines the base stones may be "York"; they are much less expensive, and make a good sound job. No rules can be given as to the depth and dimensions of foundations, as it mainly depends upon the size of the engine, head of water to be pumped, and the nature of the ground in the particular locality. As these foundations are rather costly, it is advisable to have special skilled advice upon such matters, in order to avoid any errors.

General Remarks.

Engines of the Cornish kind are only suitable where large quantities of water have to be pumped, and where the "head" or pressure is constant; otherwise there is much loss, caused by the difference of friction in the delivery pipe. Arrangements have, however, been made in large engines, by automatic valve gear, which partly compensates for this defect, and takes off the shock which the engine would otherwise receive by the difference of resistance in the down stroke of the pump plungers.

There has been much controversy as to the value of these engines for water pumping as compared with other kinds. As the author has in most instances given the consumption of fuel, &c., the designer must judge for himself the sort of engine most suitable for his particular case.

CHAPTER VIII.

BOILERS.

THE principal kinds of boilers used for water-pumping machinery are Vertical, Cylindrical, Cornish, Lancashire, and Multitubular. The various kinds of water-tube boilers cannot be recommended for such purposes, and except in a few instances, they are seldom or never used.

VERTICAL BOILERS are only used where small quantities of water have to be pumped, and where there is not sufficient space for a horizontal boiler. There are several forms of these boilers; they are, however, all constructed with a fire box; the most simple have one centre tube riveted on the top of the fire box, with three or more cross water tubes passing through the same. The top of the boiler may be made cup shape, and should be well stayed; proper mud-hole doors must be provided at the bottom part to allow for cleaning out when required.

The fittings for a 3 feet diameter by 7 feet boiler (about one of the smallest likely to be used), should be: one 2-inch safety valve, two ½-inch gauge glasses, two ½-inch water gauge cocks, one 1¼-inch blow-off cock, one 1¼-inch feed valve, and one 2-inch steam valve or solid bottom cock. The boiler should be covered with composition, and lagged with wood or sheet iron; to procure a good draught the blast pipe from the engine should be carried into the smoke pipe, the top of the pipe being contracted at the outlet.

MULTITUBULAR BOILERS (VERTICAL).—In lieu of the centre and cross tubes, the top of the fire box forms a tube plate, another one is riveted in at the top of the shell, a number of

small tubes, say $1\frac{1}{2}$ to 2 inches diameter, pass through each of these plates and are riveted to same; in all other respects the boiler is of the same construction as before.

Boilers of this kind are not so economical as to fuel as a horizontal boiler, and are only to be recommended where space is an object. It must always be remembered that in the hands of unskilled people they are not very safe to use. The steam space is small, and in case of the boiler not being properly and regularly supplied with water, the risk of an explosion is great.

Horizontal Cylindrical Boilers.—Where fuel is cheap, or where coke or breeze is intended to be used, this class of boiler may be adopted with much advantage, especially as in the most untutored hands they are perfectly safe.

Taking a 6 horse-power as an example of a small size, this should be 4 feet diameter by 12 feet 6 inches long, with a dome 18 inches diameter by 18 inches high; the shell may be $\frac{3}{8}$-inch thick and the ends $\frac{7}{16}$ inch. The shell should be made in four plates, no seam should be over the fire, the ends cup shape and solid flanged, the steam chest welded, and the top of same solid flanged; no angle iron is required. The manhole should have a ring riveted round same. This boiler should be set in brickwork with a wheel draught, the flues lined with fire brick $4\frac{1}{2}$ inches thick. The area of the firegrate must be in proportion to the kind of fuel used, not less than 1 square foot per horse-power. The fittings should be the same as named for the vertical boiler; for the water gauge and cock fittings tubes are screwed into the end of the boiler and carried through the flues, they are protected by being passed through larger pieces of pipe built in the brickwork across the flue.

The top of the boiler should never be covered with brickwork, the height to top of stone coping as a rule, say about 12 inches to 15 inches above the top of the side flues. The brickwork should always stand on a good concrete foundation, and where the soil is bad or wet this may be made in Portland cement and at least 2 feet thick, according to the nature of the soil.

For sending abroad, where there is very little skilled labour at hand, they are much to be recommended, added to which they are easily repaired, a very important consideration

in a foreign country. They take rather longer time to get up steam in the first instance from cold water, than in the case of tube boilers of the Cornish and Lancashire kind; but if the fire is properly banked up over-night the steam can be raised in the morning in nearly the same time. A good draught from the shaft is necessary. If coke or breeze is to be the fuel, the area of the firegrate must be larger than named above, and the air spaces at the firegrate also; thin bars and an extra number of spaces is the best plan in this case.

CORNISH BOILERS.—For sizes above 8 horse-power this kind of boiler is the most suitable; the diameter of the tube is about half of the shell. The plate over the fire should be Lowmoor iron, and of a length sufficient to carry it over the bridge. Taking a boiler 5 feet diameter by 16 feet long = 15 horse-power, the tube should be 32 inches diameter by $\frac{5}{16}$ thick, the shell $\frac{3}{8}$ inch, and the end plates $\frac{7}{16}$ inch thick; these should be solid flanged. Gusset stays must be provided at each end. The tube is strengthened by three L-iron rings on the outside. The steam chest 27 inches diameter by 30 inches high, solid flanged at the base, and the top may be welded in. The boiler is set in brickwork, with a wheel or split draught, the heated air passing through the tube along each side flue, and out at the flue under the boiler.

The fittings should be one 3-inch double safety valve, one $2\frac{1}{2}$-inch steam valve, two sets $\frac{5}{8}$-inch gauge glass fittings, two $\frac{3}{4}$-inch gauge cocks, one 2-inch blow-off cock, one 2-inch feed valve and back pressure valve, one float and whistling gear. The chain of the damper should be led over pulleys to the front of the boiler. The brickwork should be carried up say 15 inches above the side flue and the top of boiler, and the steam chest should be covered with non-conducting composition, together with all the steam pipes. This should be well painted, two or three coats.

LANCASHIRE BOILERS (Drawing No. 23).—When the diameter of the boiler exceeds 5 feet 9 inches to 6 feet, a boiler of this type should be used; the general construction is the same as above, except that there are two tubes in lieu of one. The maximum diameter and length of the shell should not exceed 7 feet to 7 feet 6 inches by 30 feet to 35 feet long;

it is advisable to increase the number of boilers when more steam power is wanted.

When well set in brickwork, and the top of boiler and pipes properly protected, these boilers are about the most economical to use. Large boiler capacity should always be allowed, it must be borne in mind; this is true economy, as a small boiler forced will consume *more fuel* than a *large one* properly fired. Should it be necessary to let the engine stand for several hours, the damper is closed, and the boiler becomes simply a reservoir of steam ready for immediate use at any time. The area of the firegrates should be ¾ square foot per horse-power, the length to the bridge must never exceed 6 feet.

MULTITUBULAR BOILERS.—Boilers made upon this plan do not require any setting, and are specially useful when fixed upon a pier, "jetty" wharf, or, as in some cases in London, on one of the upper floors of a building. They are made about the same as a locomotive boiler, with a fire box at one end and smoke box at the other, a tube plate being riveted at each end, through which 2, 2½, or 3-inch wrought-iron tubes are riveted. The shell is protected with felt, and lagged with wood or covered with non-conducting boiler composition.

The steam chest and fittings are the same as before described. These boilers are very economical in action, the steam can be got up rapidly, they take up much less room than the Cornish or the Lancashire boilers, a large saving is effected in the brickwork setting, and when carried on jetties or the floor of a building there is much less dead weight to support, which in most cases is a serious consideration. They are specially applicable where the boilers have to be placed in a cellar or vault, on account of the saving in excavation, and also the small amount of space taken up. In many instances the smoke shaft is made of wrought iron, and all the flues from the boilers of the same material.

VARIOUS BOILERS.—There are a few other kinds of boilers used, but no notice need be taken of them here for the purposes under consideration. Simplicity, efficiency, economy in fuel, and safety are the points to achieve in all cases. A large number of patents have been taken out from time to time, but no material advantage has been effected in any case.

All the above boilers described are the best to use for the purpose under notice, the form and dimensions of course varying according to the special case.

Feed Water Heaters.

All the feed water should be heated before it enters the boiler. This may be done up to 110°, by means of this kind of apparatus; there are several types; the exhaust steam from the engine is passed through the heater; two or three of those mostly in use will now be described.

Plain Cylinder Heaters.—A plain cylinder of wrought iron or cast iron may be fixed either vertical or horizontal, with the exhaust steam blown on the top of the water, the surplus passes off through a pipe at top of the apparatus; they are made self-feeding from an upper tank by means of a float, &c., and a gauge glass is fitted on the outside to show the level of the water. A manhole is at the bottom to allow of cleaning out at certain intervals; it has been found that much of the deposit from the water remains in this vessel, and so saves the boilers and keeps them clean.

Tube Heaters (Drawing No. 22) consist of an outer cylinder of wrought or cast iron, with a tube plate at top and bottom, fitted with 1½-inch or 2-inch copper or iron tubes. The exhaust steam passes through these tubes, the water being in the cylinder. At the top and bottom tube plate they are jointed, to enable the apparatus to be easily disconnected for cleaning the tubes and for repairs. They are most convenient when fixed vertical and standing upon three legs; they are fitted in the same way as before. This kind of heater, although more expensive than the last-named, is more efficient in action. The water being heated by passing through small tubes, the size of the apparatus is less, and a saving of room is effected.

Feed Apparatus for Boilers.

Steam Donkey Pumps are the best kind of apparatus for this purpose; the author has found the "Model" pump made by Messrs. Thornewill and Warham, of Burton-on-Trent, the most effective. They are self-contained on one bed plate, can be

worked either at a very low or a high rate of speed, and are not liable to get out of order or to stick in working like many of the "tappet" kind of steam pumps. They can either pump from or draw the water through the heater, according to the requirements of the special case. It is advisable to fix them on a brickwork foundation about 3 feet from the floor, to protect them from dirt and grit, and to be at a convenient height for oiling and starting.

INJECTORS should always be fixed in addition to the above, for use in case of any break-down with the pump. The author advises a full-size one in all cases, capable of feeding rapidly in case of any emergency. All the pipes should be put together with gun-metal faced flanges, and the holes drilled; this allows of rapid disconnection in case of a stoppage.

These apparatus are perfectly safe in the hands of *skilled people*, but on no account should others be allowed to interfere with them. A feed tank to supply the injectors, of say 30 gallons, should be fixed on top of the brickwork of the boilers, fitted with ball valve and overflow pipe. This tank should be covered at the top and carefully protected from dirt and grit; great care should be used to obtain clean water for feeding boilers, especially where injectors are used.

FURNACES FOR SMOKE CONSUMING.

There have been a large number of these brought out. The author here notices only two, which he has found to act well in practice and meet the requirements of the Smoke Act, as well as effecting a considerable economy in fuel. Many of the so-called smoke consumers are a delusion, and it is simply a waste of money to use them.

WRIGHT'S APPARATUS is a very useful type, and possesses the advantage that it can be applied to boilers at a small extra cost. It is simple and effective in action, prevents smoke, but in the economy of fuel is not equal to that named below.

JUCKES'.—This apparatus has stood the test of thirty years' constant use, and upon a very large scale. At one establishment there are about thirty in use, giving very high results as to economy.

It consists of an endless chain of cast-iron bars working over drums at each end, which travels at the rate of six feet per hour. A hopper at the front feeds the small coal, which is slowly carried forward by the chain to the bridge, thus ensuring the perfect *slow* combustion of the fuel, and the entire prevention of smoke. The supply of steam from the boiler is regular, and no injury takes place to the plate of the boiler over the fire by the opening of the door, as in the common furnace, to charge it with fuel. The fire does not require to be clinkered, it is self-acting in this respect.

They are, however, only applicable on a large scale, and where skilled labour can be had in case of a break-down to repair quickly.

The economy of fuel effected is from 25 to 30 per cent. The power required to drive them is very small; this is usually done by a separate engine, or driven off the fly-wheel of the donkey engine. The cost of the brickwork for these furnaces is much more than in ordinary furnaces.

There have been many modifications of this furnace, but the original type has never been equalled. The author believes that the original patentee, although he did so much to solve the question of smoke consuming, never reaped any substantial benefit, but like many people in such cases, sunk a large sum of money for others to reap the benefit of his ingenuity and labours.

General Remarks.

Duplicate Boilers should always be provided to be used when others are being cleaned, examined, and repaired.

The author's practice is to work each boiler for a month, then to throw it out of action, examine the interior, clean, if necessary, and carefully examine all the fittings. The flues should be cleared out once per week; but at the stopping time they should be carefully examined internally, and the outer shell of the boiler also.

The pins of the safety valves should be minutely examined and the seats cleaned. The water-gauge fittings should also have careful attention, and the feed pipes, as in many instances serious accidents have taken place through the partial stoppage of the gauge pipes by deposit from the boiler.

The Fittings should be of the highest class, and ample for the size of boiler; it must be remembered their safe working almost entirely depends upon the proper condition of the fittings. The author prefers to use double water-gauge fittings in all cases, as in the event of one set getting stopped by deposit from the boiler, the other set will probably be in good working order and condition. With regard to safety valves, it may be noted they are too often of a very indifferent kind, badly made, too small, and when made too deep in the conical seat they are apt to stick. In all cases they should be made so that they can relieve the boiler at any instant of undue pressure. In many instances proprietors of boilers have such an objection to a slight escape of steam (almost a necessity in a sensitive safety valve), that the makers will only supply deep-seated valves to please the purchaser in the above respect. This is much to be deprecated, and the engineer advising the firm should always have his own way in all these important matters.

Proving Boilers.—They should not be proved at more than 40 lbs. per square inch beyond the working pressure, say, for the average of boilers, not to exceed 100 lbs. per square inch. The proving must always be done by hydraulic pressure; it should be gradually put on, and left on for some time; during this period all parts of the shell and tube should be submitted to a careful examination. If any part should leak, the rivets or seams should be marked, but on no account should any caulking be done *while the hydraulic pressure is on the boiler.*

Fuel used will depend upon the locality; in some instances where small coal is very cheap, it may be advantageously employed, but in the London district, or any place distant from the coal fields, good clean "nut" coals, or coals about the size of a pigeon's egg, and well screened, will be found the best to use; they do not make so much clinker, give greater heat, and the cost is less in working. The amount of ash refuse is also much less.

Where gas coke can be obtained at a cheap rate it is a good fuel, and coke breeze may also be advantageously used, but in this case the furnaces must be specially constructed to burn the same. The area of the grate must be larger, and the air space

increased. More clinker will be formed than when using coke or coals. The draught must be very good from the shaft.

Water should be laid on near the coal heap, and an india-rubber hose provided to damp the coals before use. This has been found very advantageous especially when using small coal. It is also advisable to have a water pan under the fire bars to keep them cool; in some instances the draught of the shaft is much increased by this plan.

CHAPTER IX.

ENGINE AND BOILER HOUSES.

Engine Houses.

The dimensions of the houses will, of course, depend upon the size and kind of engine, and the disposition of the gear, &c.

The hôuse should be of good height, say not less than 10 to 12 feet to the wall plate, even in small houses.

The walls, when of brickwork, should not be less than 14 inches thick, and the principals of the roof of iron, with wood purlins, caulked on and bolted to the T-iron; it should be close boarded, and covered with slates, or it may be an open timber roof, stained and varnished. The walls should be plastered on the inside and painted. The floor may be wood, covered with tiles, stone paving, or, when the ground is solid below, the paving may be of Stuart's patent granolithic concrete. The author has used this material on a large scale for this and kindred purposes, and has been well satisfied with it.

The house should be well lighted, and a proper amount of ventilation provided by swing sashes. All the steam pipes should be covered with composition, and in some instances cased with wood as well.

Where any pipes have to pass under the floor, they should also be covered with composition and be placed in channels of brickwork; easy means of access for examination and repairs should be provided. In most cases the channel should be covered at top with iron plates with a few made to take up when required.

An engine counter should be provided to show the number of strokes made by the engine in a given time; the counter should be placed under glass, and in such a way that the attendants cannot interfere with it.

The engine house should be completely shut off from the boiler house, and while thorough ventilation should be provided, all damp, dust, and grit should be carefully excluded.

ENGINE HOUSES FOR CORNISH AND BEAM ENGINES must be specially constructed to suit the particular kind of engine; no rules can be given as to this—the foundations for the cylinder, main centre, and pumps, must be very massive; granite is the preferable stone to use in this case; the thickness of the walls will depend upon the kind and power of the engine.

FITTINGS OF ROOMS.—A steam gauge and vacuum gauge should be fixed on the wall, well in sight; also a pressure gauge to show the "head" of water. A set of spanners to take each size nut should be provided and kept on a rack. A girder should be fixed over the cylinder, and also at the fly-wheel shaft, for the purpose of lifting these parts of the engine when under repair; in the case of large beam or Cornish engines a traveller is sometimes provided with lifting crab and strong tackle.

ENGINE DRIVERS.—The author always advises that the engine should be got up bright in all the usual parts; and when this is the case the men take more pride in keeping the machinery in good order. A system of bonuses in this case, as well as with the stoker, is advisable, when the engines have been kept going well up to their work, with a consumption of oil, &c., not exceeding a certain fixed amount per month.

It is almost needless to say that where Cornish or the larger kind of compound engines are used, only skilled mechanics should be employed, the machines being of a costly character and of large power; in case of any emergency arising those in charge should be competent to deal with it both with expedition and skill. From a long experience in such matters, the author may state he has always found the employment of well experienced men pays best in the end; if the proprietors do otherwise it is very false economy, and nearly sure to lead to serious accidents, not only to the machinery but to human life.

Boiler Houses.

The houses should be of fair height, say not less than 6 feet 6 inches from the top of the boiler to the under side of the tie beam of the roof. The walls, when of brickwork, should not be less than 14 inches thick; it is desirable to plaster the inside walls.

The roof may be constructed with iron trusses with wood purlins covered with boards to fix the slates on. At the top a lantern or ventilator should be provided with glazed "swing" sashes, or louvres, capable of adjustment by cords from the floor of the boiler house.

The floor in front of the boilers should be iron plates, for say at least 4 feet wide; the rest may be paved with stone or covered with asphalte or Stuart's patent granolithic paving, before named. A channel of brickwork should be formed in front of the boiler for the blow-off pipes, with a door and frame over each cock.

The stoking space in front of the boiler must not be less than 8 feet; the coals may either be kept in an iron bunker at the back of the stoking floor or at the side of the boiler. In some cases it is more convenient to run the coals into the houses in iron trucks on three wheels, the front one being made to swivel, and fitted with a sliding hopper to take the coals as required.

A water pipe with hose, as before named, should be provided to sprinkle the coals occasionally, and for the purpose of quenching the fire if it has to be drawn in case of any emergency. Provision should be made either at the front or back wall for taking out the boiler if required.

Brickwork Shafts.—No rule can be given for the height and area of these, as it depends upon the number of boilers, fuel, and also as to the position in relation to the surrounding buildings. When constructed in London, the Building Act requires that the diameter outside at the base should not be less than one-tenth the height, and the thickness of brickwork according to the height.

The shape of the shaft may be round, square, or octagon; the author generally prefers them round as they keep cleaner, and present a nicer exterior appearance. The top cap may be

cast iron, and painted white to look like stone; it is much less in weight, added to which the brickwork is better protected by iron than stone, and is safer in every respect. A large flue door should be left at the base of shaft, and a pocket for the soot of not less than 3 feet *below* the main flue into the shaft; any greater depth in most cases will much interfere with the draught. The lower part of the shaft and flues must be kept free from water and damp.

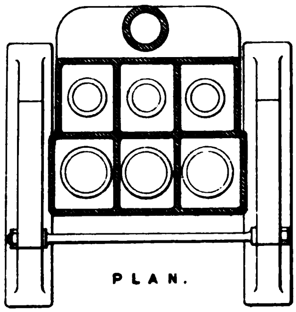
Labour in the Boiler House.

In large places the boilers should be attended to by men who should have no other duties to perform than to look after them; the feeding apparatus should *in all cases* be in the boiler house, and independent of the engines. To ensure careful attention and economy in the use of the fuel, good wages should be paid to efficient men, and a small premium paid monthly upon any saving of coals effected below a certain fixed amount, in proportion to the number of hours at work and work done in the mill or factory. All the parts of the house should be kept very clean, and the fittings well polished. When all things are in good order the men take extra interest in the place, the work is always better done, and the apparatus better cared for in every way. It is advisable to have clear rules or instructions in writing fixed on the walls of the boiler house, as to the duties of men, viz. regular supply of feed water, periodical trial of water gauges, when to open the blow-off cocks, banking of fires —and especially that no outside person should be allowed on any account to interfere with any part of the boilers or fittings. In the author's experience many unfortunate accidents have been caused by such interference. Strangers and those who have no business in the houses should at all times be rigidly excluded.

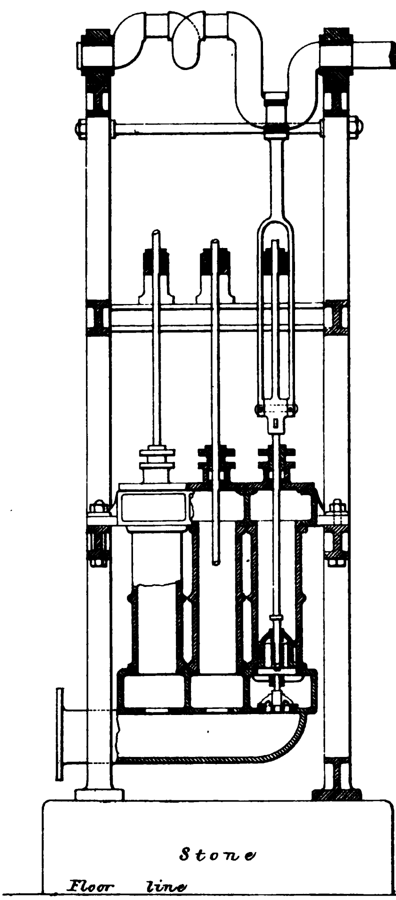
INDEX.

LONDON: PRINTED BY WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

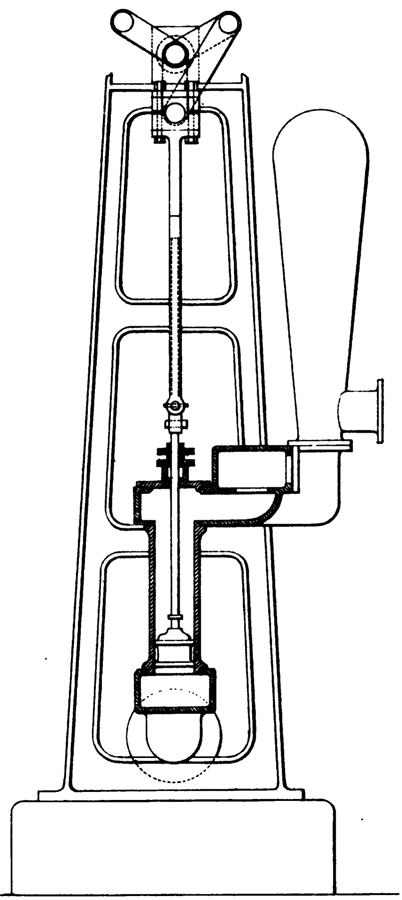
THREE THROW LIFT PUMPS.



PLAN.



SECTION.



SIDE ELEVATION.

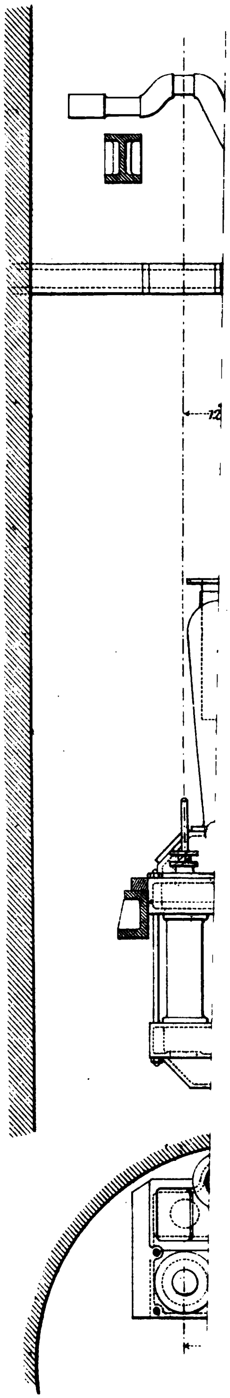
M P

Scale of Feet

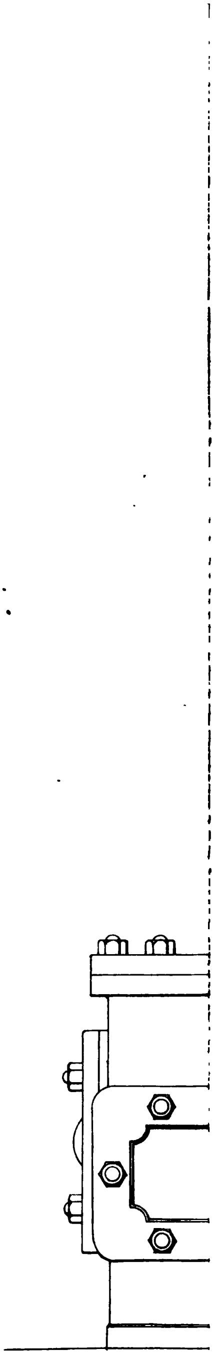
Ins. 12 . 9 . 6 . 3 . 0 1 2 3 4 5 6 Feet

E. & F. N. Spon, London & New York.

THOS. KELL & SON



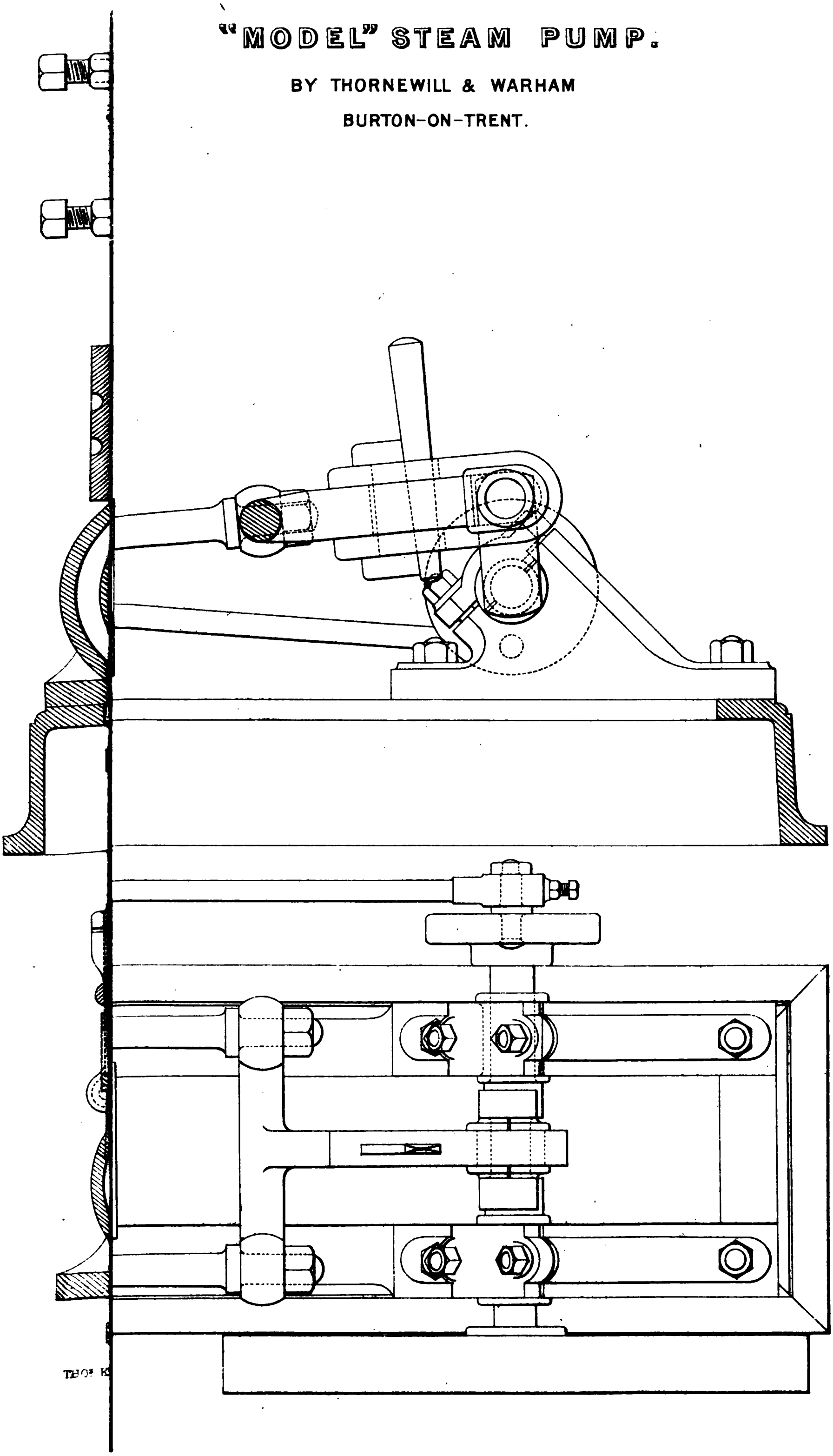
E. & F. N. Spon, London.



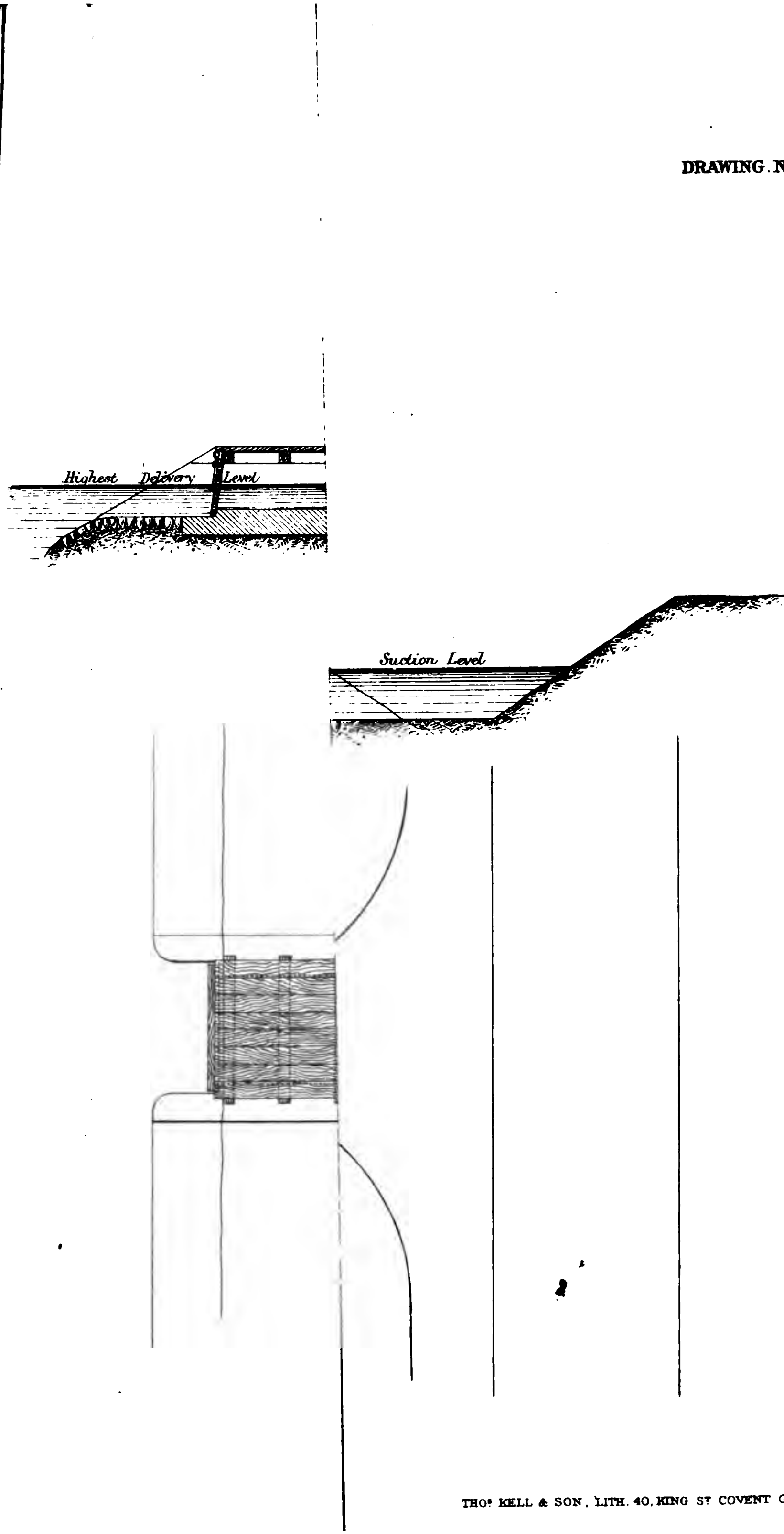
"MODEL" STEAM PUMP.

BY THORNEWILL & WARHAM

BURTON-ON-TRENT.

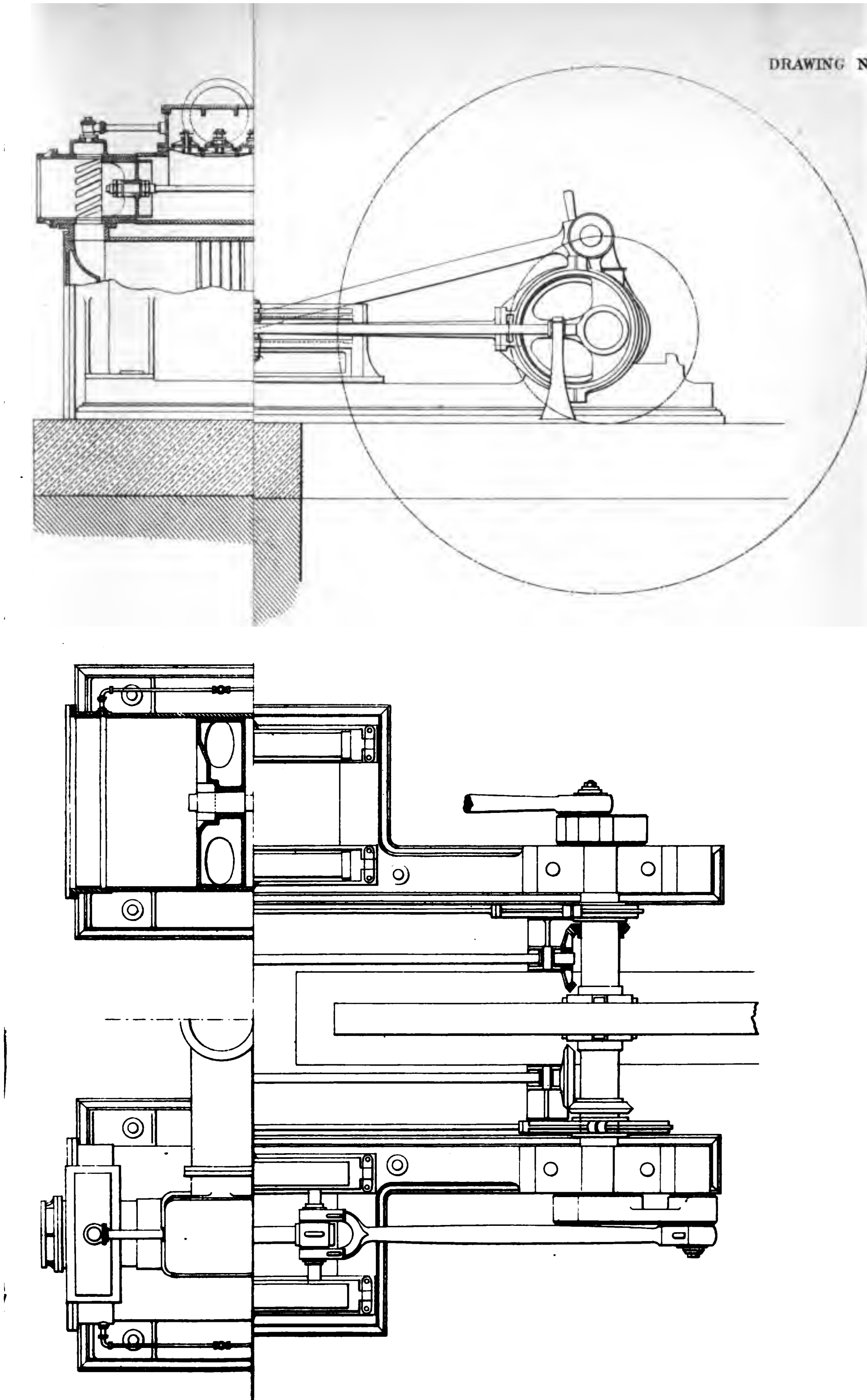


DRAWING. Nº 5.

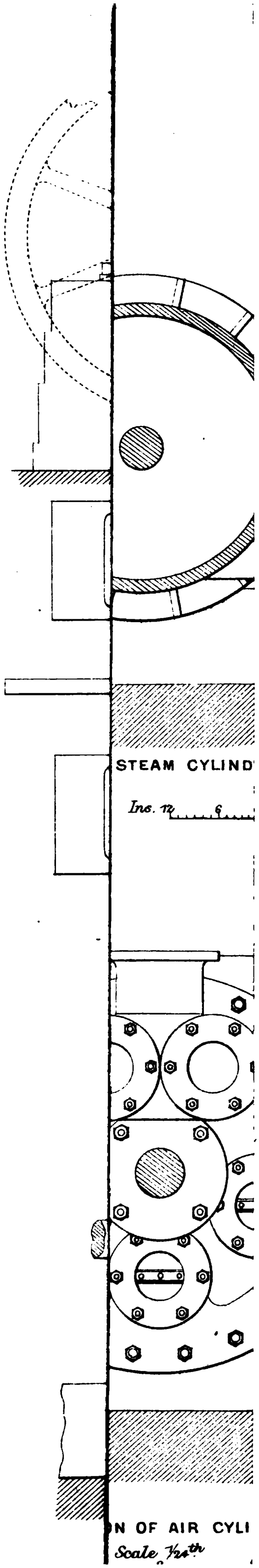


THOˢ KELL & SON, LITH. 40, KING Sᵀ COVENT GARDEN.

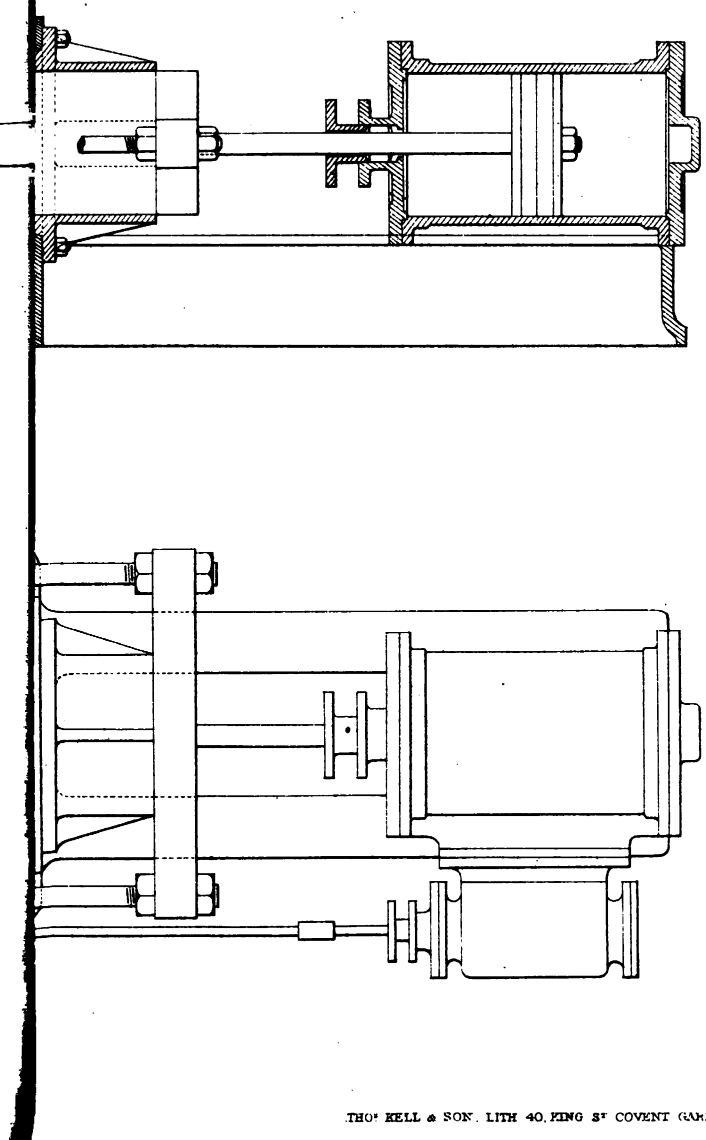
DRAWING N° 6.



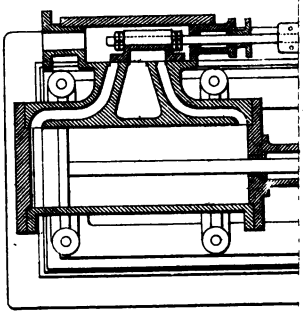
E & F.N. Spon London & New

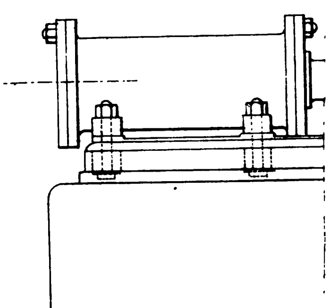

STEAM CYLIND
Ins. 12 6
N OF AIR CYLI
Scale 1/24th

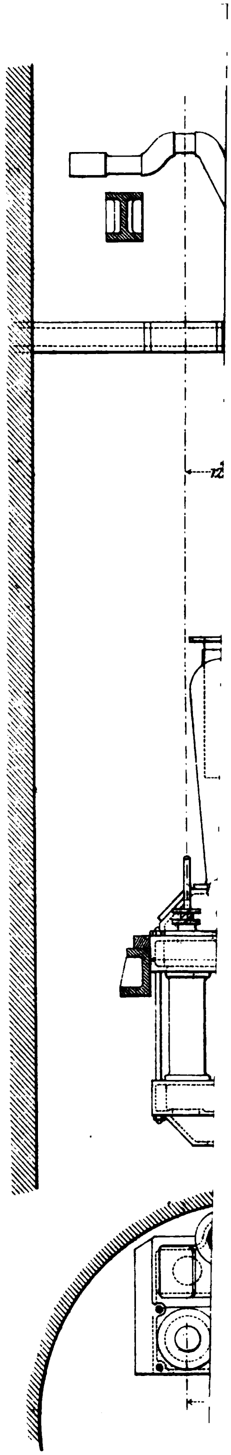
DRAWING Nº 9.



THOˢ KELL & SON. LITH 40, KING Sᵀ COVENT GARDEN





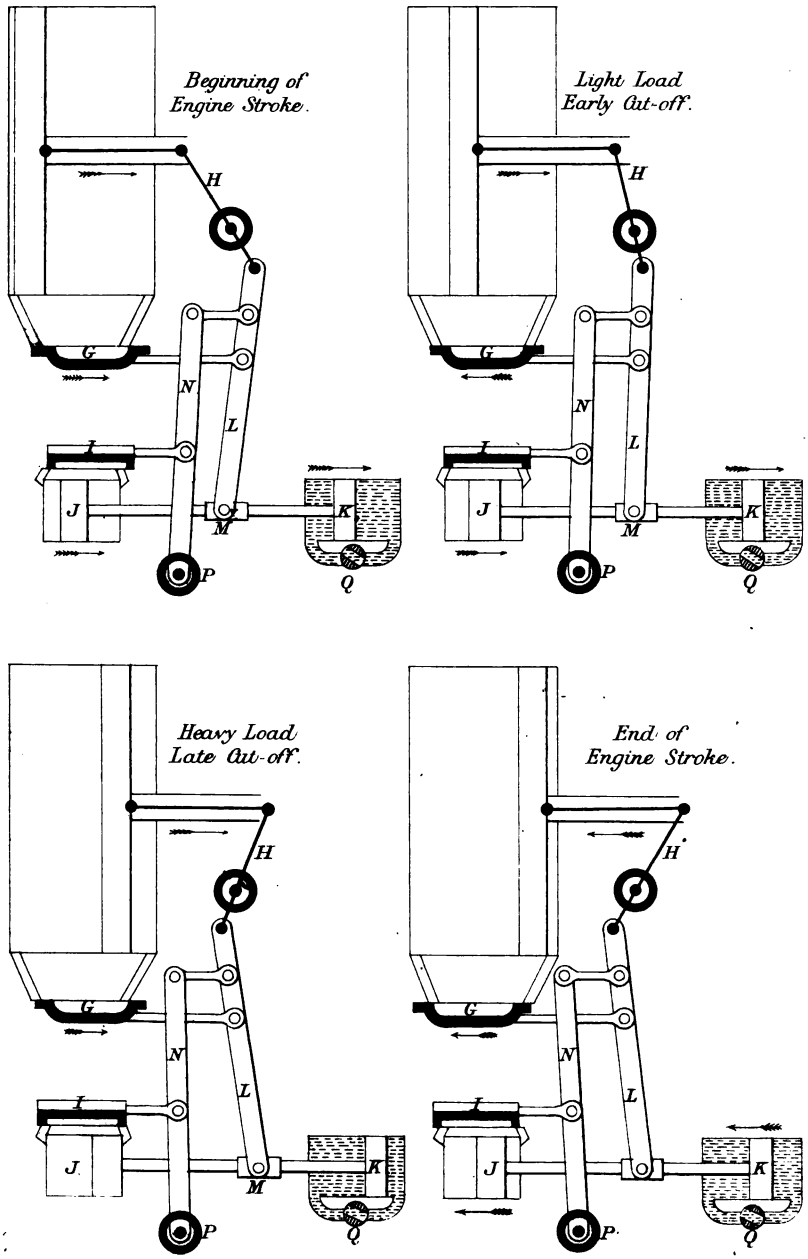


E & F.N. Spon, London.

COMPOUND DIFFERENTIAL ENGINES.

Diagrams.

Illustrating Action of Differential Valve Gear.

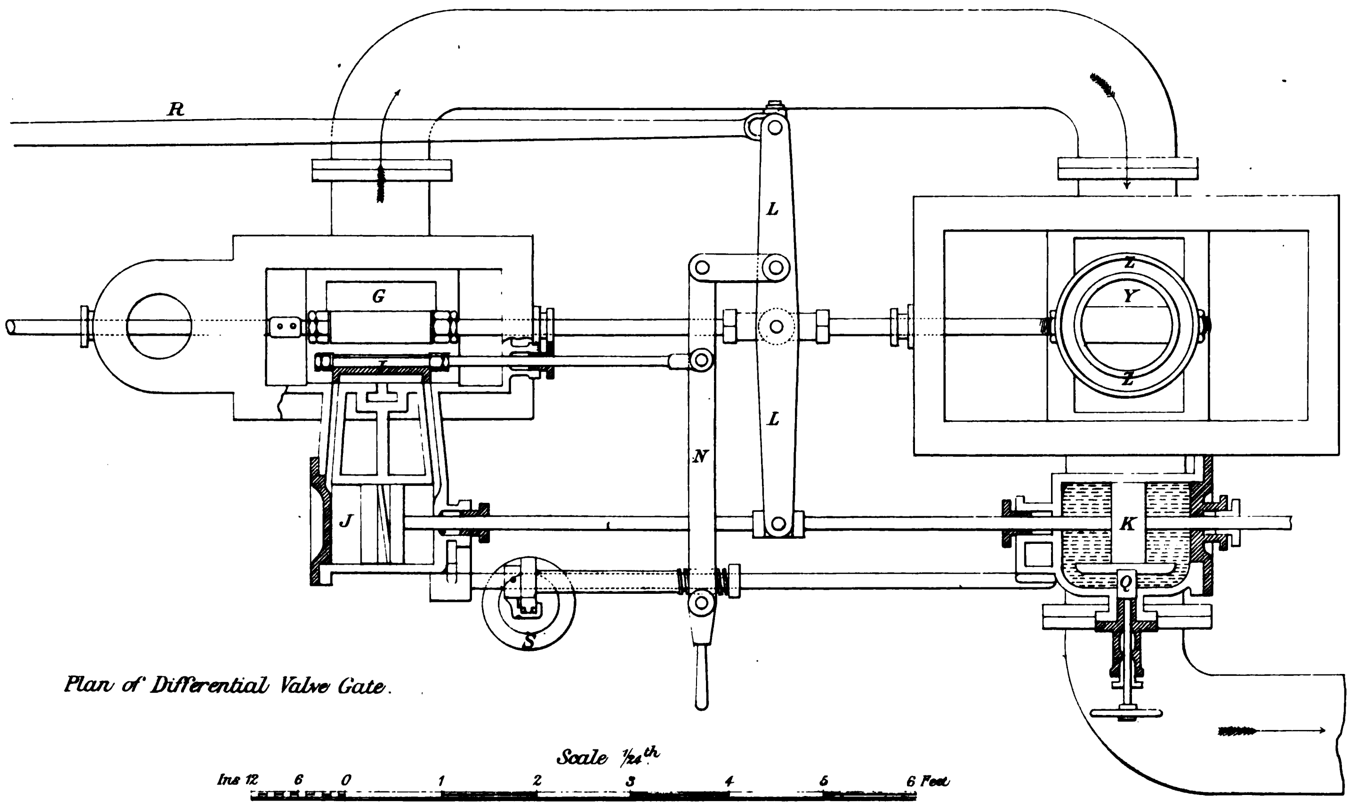


E. & F. N. Spon, London & New York.

THOS KELL & SON, LITH.

DRAWING Nº 40.

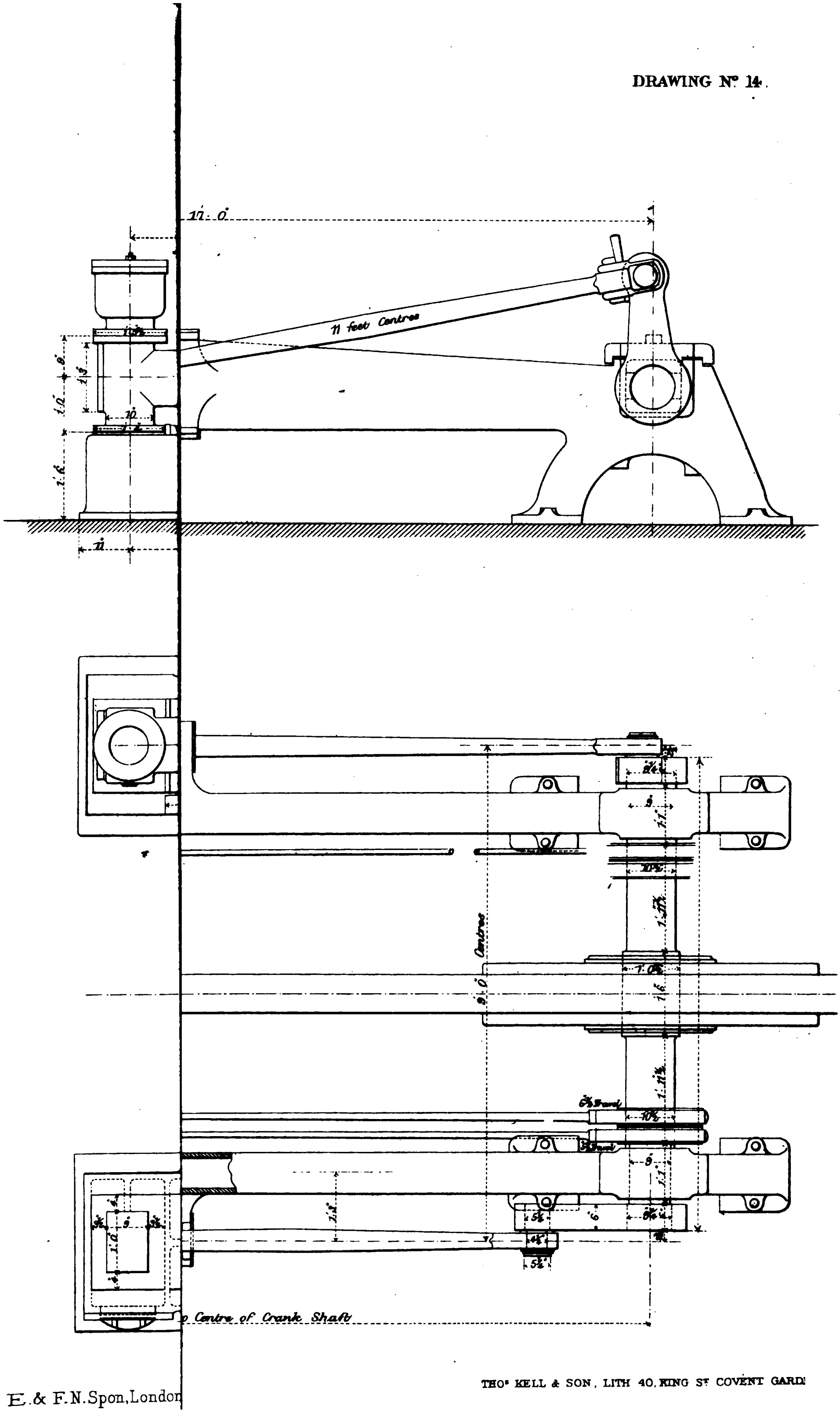
COMPOUND DIFFERENTIAL ENGINE.



Plan of Differential Valve Gate.

E.& F.N. Spon, London & New York

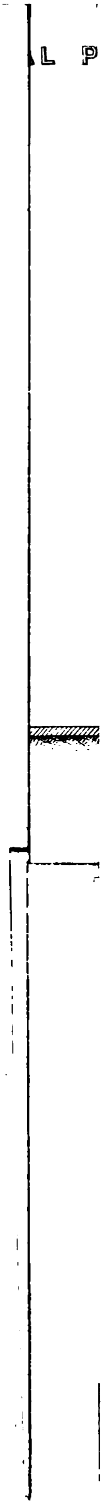
THOS KELL & SON, LITH



E. & F. N. Spon, London

THOˢ KELL & SON, LITH 40, KING Sᵀ COVENT GARDᴺ

L P

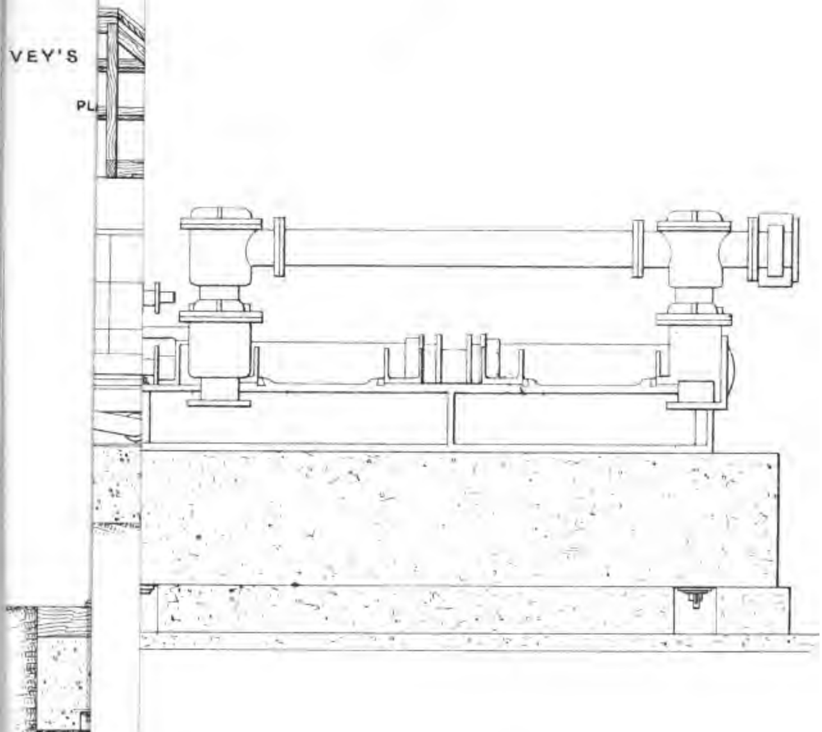


THOS KELL & SON LITH 40 KI

RAWING I

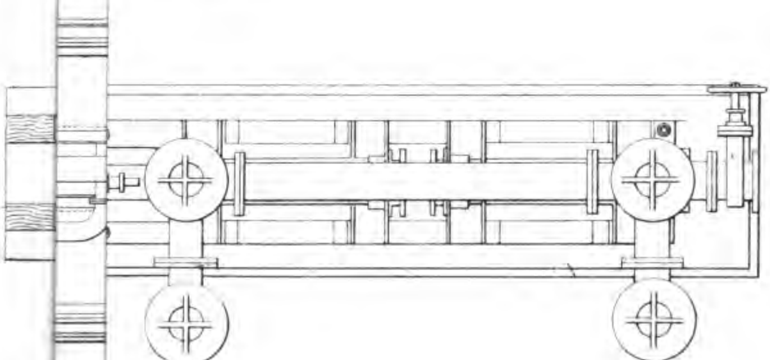
VEY'S

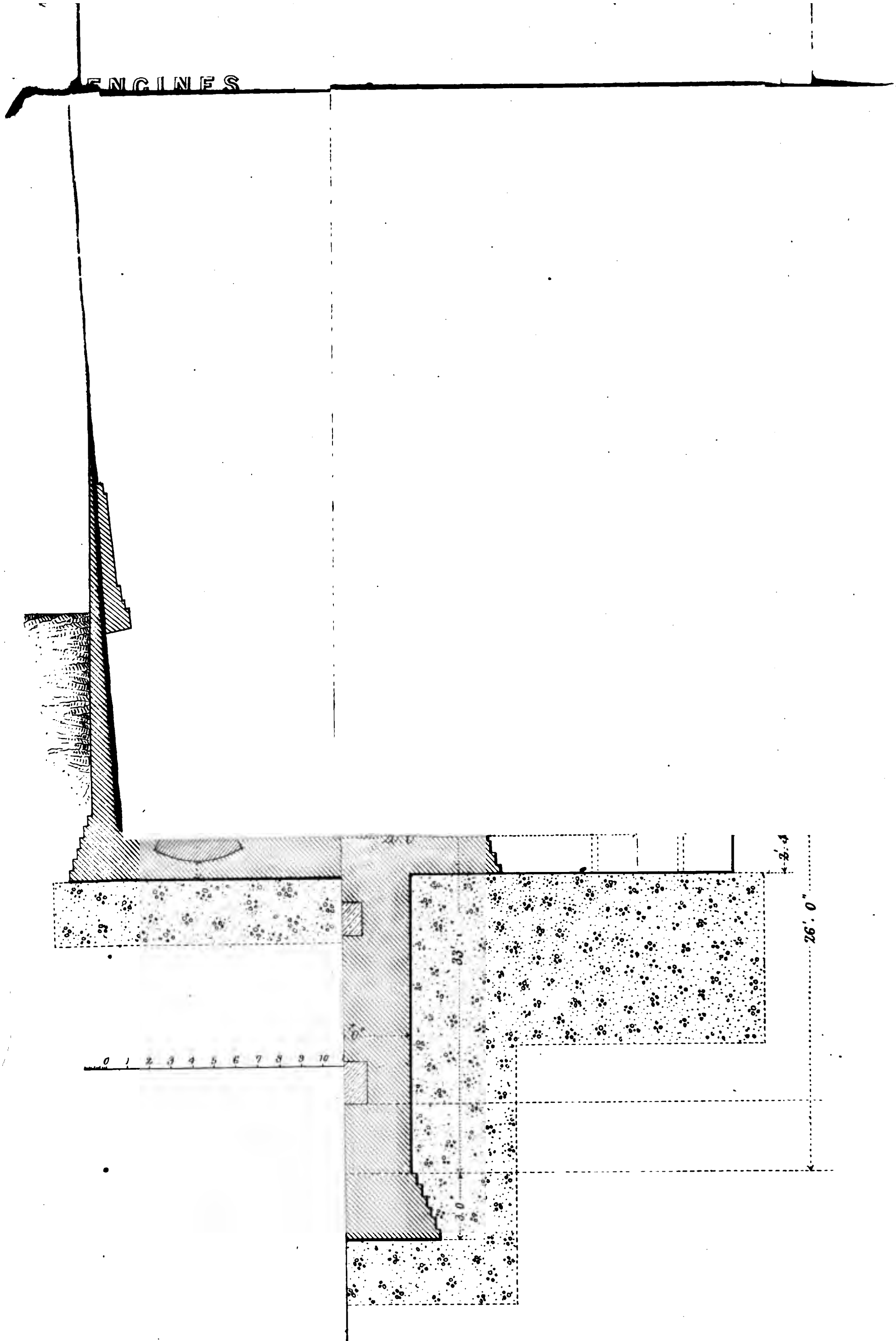
PL



eet

25,000 Gall.s per hour
of 130 Yds. (Low Moor)



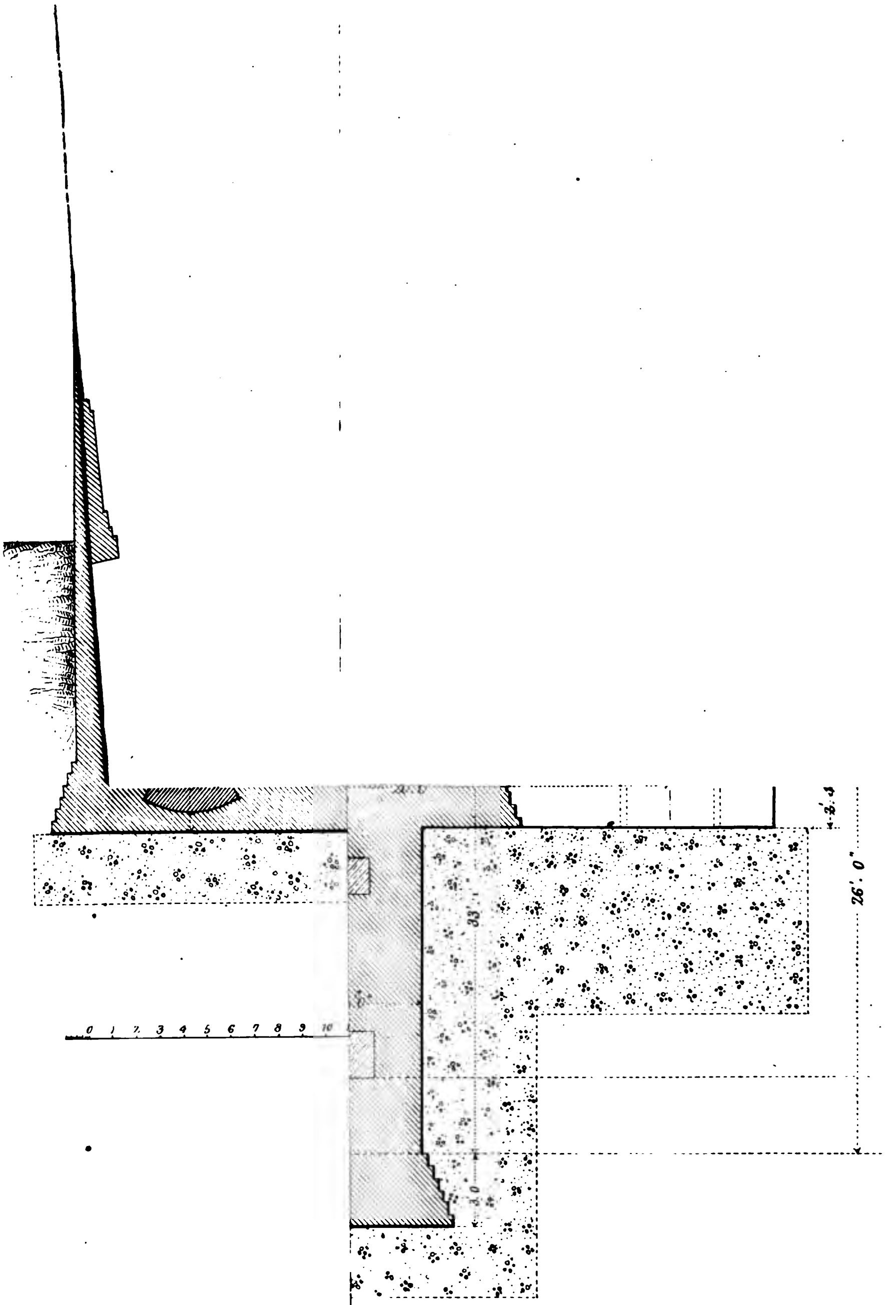


E.& F.N. Spon, London & New York.

THOS KELL & SON. LITH. 40, KING ST COVENT GAR

ENGINES.

D FT STROKE.

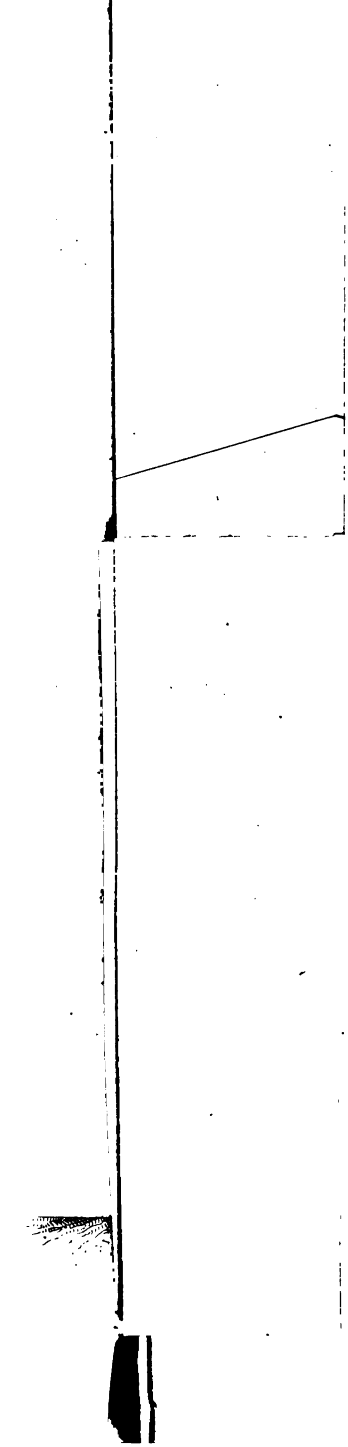


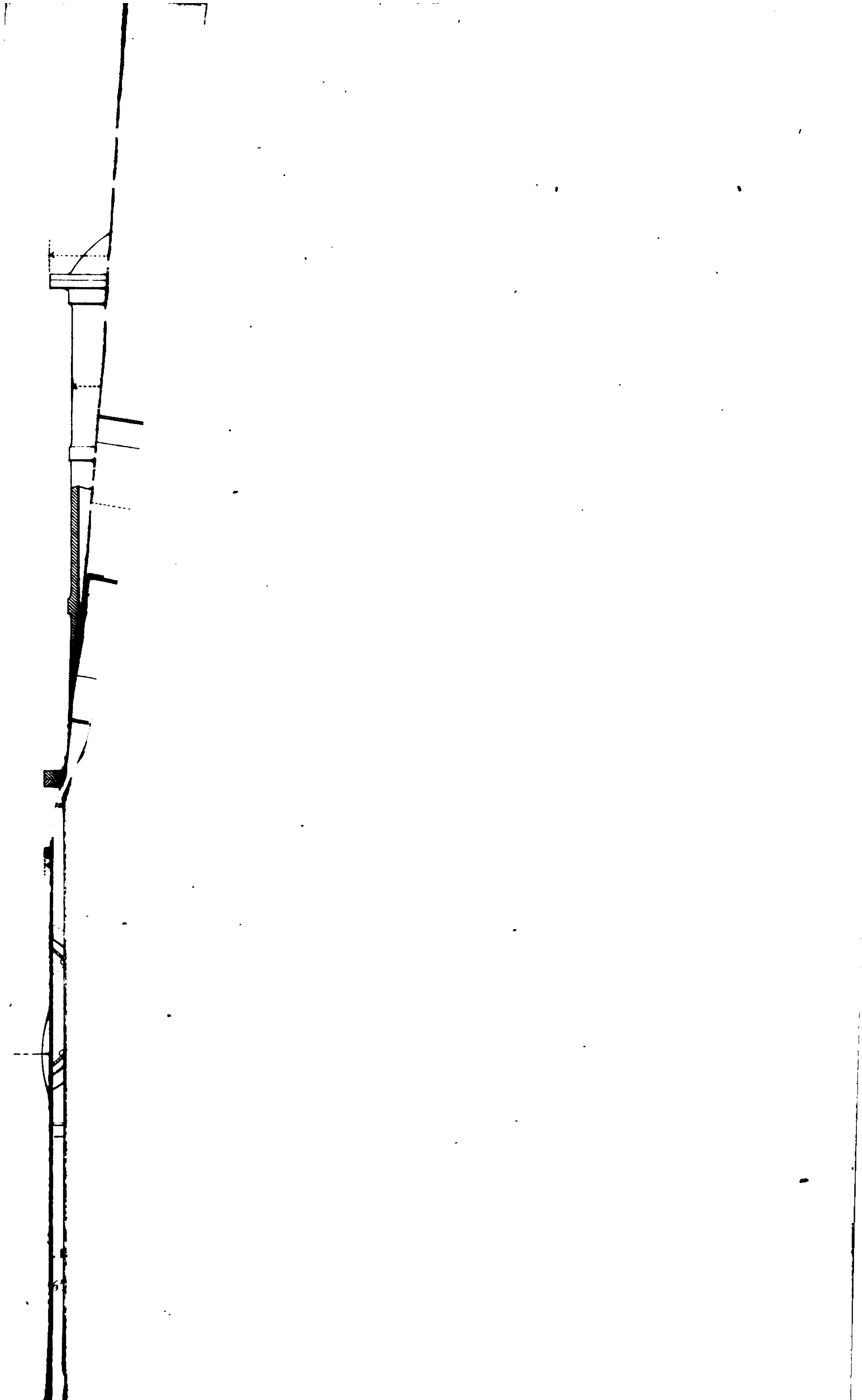
E. & F. N. Spon, London & New York.

THOs KELL & SON, LITH. 40, KING St COVENT GARDEN.

ENGINES.

0 FT STROKE.





1886.

BOOKS RELATING

TO

APPLIED SCIENCE

PUBLISHED BY

E. & F. N. SPON,

LONDON: 125, STRAND.

NEW YORK: 35, MURRAY STREET.

A Pocket-Book for Chemists, Chemical Manufacturers, Metallurgists, Dyers, Distillers, Brewers, Sugar Refiners, Photographers, Students, etc., etc. By THOMAS BAYLEY, Assoc. R.C. Sc. Ireland, Analytical and Consulting Chemist and Assayer. Fourth edition, with additions, 437 pp., royal 32mo, roan, gilt edges, 5*s*.

SYNOPSIS OF CONTENTS:

Atomic Weights and Factors—Useful Data—Chemical Calculations—Rules for Indirect Analysis—Weights and Measures—Thermometers and Barometers—Chemical Physics—Boiling Points, etc.—Solubility of Substances—Methods of Obtaining Specific Gravity—Conversion of Hydrometers—Strength of Solutions by Specific Gravity—Analysis—Gas Analysis—Water Analysis—Qualitative Analysis and Reactions—Volumetric Analysis—Manipulation—Mineralogy—Assaying—Alcohol—Beer—Sugar—Miscellaneous Technological matter relating to Potash, Soda, Sulphuric Acid, Chlorine, Tar Products, Petroleum, Milk, Tallow, Photography, Prices, Wages, Appendix, etc., etc.

The Mechanician: A Treatise on the Construction and Manipulation of Tools, for the use and instruction of Young Engineers and Scientific Amateurs, comprising the Arts of Blacksmithing and Forging; the Construction and Manufacture of Hand Tools, and the various Methods of Using and Grinding them; the Construction of Machine Tools, and how to work them; Machine Fitting and Erection; description of Hand and Machine Processes; Turning and Screw Cutting; principles of Constructing and details of Making and Erecting Steam Engines, and the various details of setting out work, etc., etc. By CAMERON KNIGHT, Engineer. *Containing* 1147 *illustrations*, and 397 pages of letter-press. Third edition, 4to, cloth, 18*s*.

B

On Designing Belt Gearing. By E. J. COWLING WELCH, Mem. Inst. Mech. Engineers, Author of 'Designing Valve Gearing.' Fcap. 8vo, sewed, 6*d.*

A Handbook of Formulæ, Tables, and Memoranda, for Architectural Surveyors and others engaged in Building. By J. T. HURST, C.E. Thirteenth edition, royal 32mo, roan, 5*s.*

"It is no disparagement to the many excellent publications we refer to, to say that in our opinion this little pocket-book of Hurst's is the very best of them all, without any exception. It would be useless to attempt a recapitulation of the contents, for it appears to contain almost *everything* that anyone connected with building could require, and, best of all, made up in a compact form for carrying in the pocket, measuring only 5 in. by 3 in., and about ½ in. thick, in a limp cover. We congratulate the author on the success of his laborious and practically compiled little book, which has received unqualified and deserved praise from every professional person to whom we have shown it."—*The Dublin Builder.*

Tabulated Weights of Angle, Tee, Bulb, Round, Square, and Flat Iron and Steel, and other information for the use of Naval Architects and Shipbuilders. By C. H. JORDAN, M.I.N.A. Fourth edition, 32mo, cloth, 2*s.* 6*d.*

Quantity Surveying. By J. LEANING. With 42 illustrations, crown 8vo, cloth, 9*s.*

CONTENTS:

A complete Explanation of the London Practice.
General Instructions.
Order of Taking Off.
Modes of Measurement of the various Trades.
Use and Waste.
Ventilation and Warming.
Credits, with various Examples of Treatment.
Abbreviations.
Squaring the Dimensions.
Abstracting, with Examples in illustration of each Trade.
Billing.
Examples of Preambles to each Trade.
Form for a Bill of Quantities.
Do. Bill of Credits.
Do. Bill for Alternative Estimate.
Restorations and Repairs, and Form of Bill.
Variations before Acceptance of Tender.
Errors in a Builder's Estimate.
Schedule of Prices.
Form of Schedule of Prices.
Analysis of Schedule of Prices.
Adjustment of Accounts.
Form of a Bill of Variations.
Remarks on Specifications.
Prices and Valuation of Work, with Examples and Remarks upon each Trade.
The Law as it affects Quantity Surveyors, with Law Reports.
Taking Off after the Old Method.
Northern Practice.
The General Statement of the Methods recommended by the Manchester Society of Architects for taking Quantities.
Examples of Collections.
Examples of "Taking Off" in each Trade.
Remarks on the Past and Present Methods of Estimating.

A Practical Treatise on Heat, as applied to the Useful Arts; for the Use of Engineers, Architects, &c. By THOMAS BOX. *With* 14 *plates.* Third edition, crown 8vo, cloth, 12*s.* 6*d.*

A Descriptive Treatise on Mathematical Drawing Instruments: their construction, uses, qualities, selection, preservation, and suggestions for improvements, with hints upon Drawing and Colouring. By W. F. STANLEY, M.R.I. Fifth edition, *with numerous illustrations,* crown 8vo, cloth, 5*s.*

Spons' Architects' and Builders' Pocket-Book of Prices and Memoranda. Edited by W. YOUNG, Architect. Royal 32mo, roan, 4*s.* 6*d.*; or cloth, red edges, 3*s.* 6*d.* *Published annually.* Thirteenth edition. *Now ready.*

Long-Span Railway Bridges, comprising Investigations of the Comparative Theoretical and Practical Advantages of the various adopted or proposed Type Systems of Construction, with numerous Formulæ and Tables giving the weight of Iron or Steel required in Bridges from 300 feet to the limiting Spans; to which are added similar Investigations and Tables relating to Short-span Railway Bridges. Second and revised edition. By B. BAKER, Assoc. Inst. C.E. *Plates,* crown 8vo, cloth, 5*s.*

Elementary Theory and Calculation of Iron Bridges and Roofs. By AUGUST RITTER, Ph.D., Professor at the Polytechnic School at Aix-la-Chapelle. Translated from the third German edition, by H. R. SANKEY, Capt. R.E. With 500 *illustrations,* 8vo, cloth, 15*s.*

The Builder's Clerk: a Guide to the Management of a Builder's Business. By THOMAS BALES. Fcap. 8vo, cloth, 1*s.* 6*d.*

The Elementary Principles of Carpentry. By THOMAS TREDGOLD. Revised from the original edition, and partly re-written, by JOHN THOMAS HURST. Contained in 517 pages of letter-press, and *illustrated with* 48 *plates and* 150 *wood engravings.* Fourth edition, reprinted from the third, crown 8vo, cloth, 12*s.* 6*d.*

Section I. On the Equality and Distribution of Forces—Section II. Resistance of Timber—Section III. Construction of Floors—Section IV. Construction of Roofs—Section V. Construction of Domes and Cupolas—Section VI. Construction of Partitions—Section VII. Scaffolds, Staging, and Gantries—Section VIII. Construction of Centres for Bridges—Section IX. Coffer-dams, Shoring, and Strutting—Section X. Wooden Bridges and Viaducts—Section XI. Joints, Straps, and other Fastenings—Section XII. Timber.

Our Factories, Workshops, and Warehouses: their Sanitary and Fire-Resisting Arrangements. By B. H. THWAITE, Assoc. Mem. Inst. C.E. *With* 183 *wood engravings,* crown 8vo, cloth, 9*s.*

Gold: Its Occurrence and Extraction, embracing the Geographical and Geological Distribution and the Mineralogical Characters of Gold-bearing rocks; the peculiar features and modes of working Shallow Placers, Rivers, and Deep Leads; Hydraulicing; the Reduction and Separation of Auriferous Quartz; the treatment of complex Auriferous ores containing other metals; a Bibliography of the subject and a Glossary of Technical and Foreign Terms. By ALFRED G. LOCK, F.R.G.S. *With numerous illustrations and maps,* 1250 pp., super-royal 8vo, cloth, 2*l.* 12*s.* 6*d.*

A Practical Treatise on Coal Mining. By GEORGE G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Member of the Society of Engineers. *With* 82 *lithographic plates.* 2 vols., royal 4to, cloth, 3*l.* 12*s.*

Iron Roofs: Examples of Design, Description. *Illustrated with* 64 *Working Drawings of Executed Roofs.* By ARTHUR T. WALMISLEY, Assoc. Mem. Inst. C.E. Imp. 4to, half-morocco, £2 12*s.* 6*d.*

A History of Electric Telegraphy, to the Year 1837. Chiefly compiled from Original Sources, and hitherto Unpublished Documents, by J. J. FAHIE, Mem. Soc. of Tel. Engineers, and of the International Society of Electricians, Paris. Crown 8vo, cloth, 9*s.*

Spons' Information for Colonial Engineers. Edited by J. T. HURST. Demy 8vo, sewed.

No. 1, Ceylon. By ABRAHAM DEANE, C.E. 2*s.* 6*d.*

CONTENTS:

Introductory Remarks — Natural Productions — Architecture and Engineering — Topography, Trade, and Natural History—Principal Stations—Weights and Measures, etc., etc.

No. 2. Southern Africa, including the Cape Colony, Natal, and the Dutch Republics. By HENRY HALL, F.R.G.S., F.R.C.I. With Map. 3*s.* 6*d.*

CONTENTS:

General Description of South Africa—Physical Geography with reference to Engineering Operations—Notes on Labour and Material in Cape Colony—Geological Notes on Rock Formation in South Africa—Engineering Instruments for Use in South Africa—Principal Public Works in Cape Colony: Railways, Mountain Roads and Passes, Harbour Works, Bridges, Gas Works, Irrigation and Water Supply, Lighthouses, Drainage and Sanitary Engineering, Public Buildings, Mines—Table of Woods in South Africa—Animals used for Draught Purposes—Statistical Notes—Table of Distances—Rates of Carriage, etc.

No. 3. India. By F. C. DANVERS, Assoc. Inst. C.E. With Map. 4*s.* 6*d.*

CONTENTS:

Physical Geography of India—Building Materials—Roads—Railways—Bridges—Irrigation — River Works — Harbours — Lighthouse Buildings — Native Labour — The Principal Trees of India—Money—Weights and Measures—Glossary of Indian Terms, etc.

A Practical Treatise on Casting and Founding, including descriptions of the modern machinery employed in the art. By N. E. SPRETSON, Engineer. Third edition, with 82 *plates* drawn to scale, 412 pp., demy 8vo, cloth, 18*s.*

Steam Heating for Buildings; or, Hints to Steam Fitters, being a description of Steam Heating Apparatus for Warming and Ventilating Private Houses and Large Buildings, with remarks on Steam, Water, and Air in their relation to Heating. By W. J. BALDWIN. *With many illustrations.* Fourth edition, crown 8vo, cloth, 10*s.* 6*d.*

The Depreciation of Factories and their Valuation. By EWING MATHESON, M. Inst. C.E. 8vo, cloth, 6*s.*

A Handbook of Electrical Testing. By H. R. KEMPE, M.S.T.E. Third edition, revised and enlarged, crown 8vo, cloth, 15*s.*

Gas Works: their Arrangement, Construction, Plant, and Machinery. By F. COLYER, M. Inst. C.E. *With* 31 *folding plates*, 8vo, cloth, 24*s.*

The Clerk of Works: a Vade-Mecum for all engaged in the Superintendence of Building Operations. By G. G. HOSKINS, F.R.I.B.A. Third edition, fcap. 8vo, cloth, 1*s.* 6*d.*

American Foundry Practice: Treating of Loam, Dry Sand, and Green Sand Moulding, and containing a Practical Treatise upon the Management of Cupolas, and the Melting of Iron. By T. D. WEST, Practical Iron Moulder and Foundry Foreman. Second edition, *with numerous illustrations*, crown 8vo, cloth, 10*s.* 6*d.*

The Maintenance of Macadamised Roads. By T. CODRINGTON, M.I.C.E., F.G.S., General Superintendent of County Roads for South Wales. 8vo, cloth, 6*s.*

Hydraulic Steam and Hand Power Lifting and Pressing Machinery. By FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E. *With* 73 *plates*, 8vo, cloth, 18*s.*

Pumps and Pumping Machinery. By F. COLYER, M.I.C.E., M.I.M.E. *With* 23 *folding plates*, 8vo, cloth, 12*s.* 6*d.*

The Municipal and Sanitary Engineer's Handbook. By H. PERCY BOULNOIS, Mem. Inst. C.E., Borough Engineer, Portsmouth. *With numerous illustrations*, demy 8vo, cloth, 12*s.* 6*d.*

CONTENTS:

The Appointment and Duties of the Town Surveyor—Traffic—Macadamised Roadways—Steam Rolling—Road Metal and Breaking—Pitched Pavements—Asphalte—Wood Pavements—Footpaths—Kerbs and Gutters—Street Naming and Numbering—Street Lighting—Sewerage—Ventilation of Sewers—Disposal of Sewage—House Drainage—Disinfection—Gas and Water Companies, &c., Breaking up Streets—Improvement of Private Streets—Borrowing Powers—Artizans' and Labourers' Dwellings—Public Conveniences—Scavenging, including Street Cleansing—Watering and the Removing of Snow—Planting Street Trees—Deposit of Plans—Dangerous Buildings—Hoardings—Obstructions—Improving Street Lines—Cellar Openings—Public Pleasure Grounds—Cemeteries—Mortuaries—Cattle and Ordinary Markets—Public Slaughter-houses, etc.—Giving numerous Forms of Notices, Specifications, and General Information upon these and other subjects of great importance to Municipal Engineers and others engaged in Sanitary Work.

Tables of the Principal Speeds occurring in Mechanical Engineering, expressed in metres in a second. By P. KEERAYEFF, Chief Mechanic of the Obouchoff Steel Works, St. Petersburg; translated by SERGIUS KERN, M.E. Fcap. 8vo, sewed, *6d.*

A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber; with Remarks on the Means of Preserving Wood from Destruction by Sea-Worms, Beetles, Ants, etc. By THOMAS ALLEN BRITTON, late Surveyor to the Metropolitan Board of Works, etc., etc. *With* 10 *plates*, crown 8vo, cloth, 7*s.* 6*d.*

Metrical Tables. By G. L. MOLESWORTH, M.I.C.E. 32mo, cloth, 1*s.* 6*d.*

CONTENTS.

General—Linear Measures—Square Measures—Cubic Measures—Measures of Capacity—Weights—Combinations—Thermometers.

Elements of Construction for Electro-Magnets. By Count TH. DU MONCEL, Mem. de l'Institut de France. Translated from the French by C. J. WHARTON. Crown 8vo, cloth, 4*s.* 6*d.*

Electro-Telegraphy. By FREDERICK S. BEECHEY, Telegraph Engineer. A Book for Beginners. *Illustrated.* Fcap. 8vo, sewed, 6*d.*

Handrailing: by the Square Cut. By JOHN JONES, Staircase Builder. Part Second, *with eight plates*, 8vo, cloth, 3*s.* 6*d.*

Practical Electrical Units Popularly Explained, with *numerous illustrations* and Remarks. By JAMES SWINBURNE, late of J. W. Swan and Co., Paris, late of Brush-Swan Electric Light Company, U.S.A. 18mo, cloth, 1*s.* 6*d.*

Philipp Reis, Inventor of the Telephone: A Biographical Sketch. With Documentary Testimony, Translations of the Original Papers of the Inventor, &c. By SILVANUS P. THOMPSON, B.A., Dr. Sc., Professor of Experimental Physics in University College, Bristol. *With illustrations*, 8vo, cloth, 7*s.* 6*d.*

A Treatise on the Use of Belting for the Transmission of Power. By J. H. COOPER. Second edition, *illustrated*, 8vo, cloth, 15*s.*

A Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers. By GUILFORD L. MOLESWORTH, Mem. Inst. C.E., Consulting Engineer to the Government of India for State Railways. *With numerous illustrations*, 744 pp. Twenty-first edition, revised and enlarged, 32mo, roan, 6*s*.

SYNOPSIS OF CONTENTS:

Surveying, Levelling, etc.—Strength and Weight of Materials—Earthwork, Brickwork, Masonry, Arches, etc.—Struts, Columns, Beams, and Trusses—Flooring, Roofing, and Roof Trusses—Girders, Bridges, etc.—Railways and Roads—Hydraulic Formulæ—Canals, Sewers, Waterworks, Docks—Irrigation and Breakwaters—Gas, Ventilation, and Warming—Heat, Light, Colour, and Sound—Gravity: Centres, Forces, and Powers—Millwork, Teeth of Wheels, Shafting, etc.—Workshop Recipes—Sundry Machinery—Animal Power—Steam and the Steam Engine—Water-power, Water-wheels, Turbines, etc.—Wind and Windmills—Steam Navigation, Ship Building, Tonnage, etc.—Gunnery, Projectiles, etc.—Weights, Measures, and Money—Trigonometry, Conic Sections, and Curves—Telegraphy—Mensuration—Tables of Areas and Circumference, and Arcs of Circles—Logarithms, Square and Cube Roots, Powers—Reciprocals, etc.—Useful Numbers—Differential and Integral Calculus—Algebraic Signs—Telegraphic Construction and Formulæ.

Spons' Tables and Memoranda for Engineers; selected and arranged by J. T. HURST, C.E., Author of 'Architectural Surveyors' Handbook,' 'Hurst's Tredgold's Carpentry,' etc. Seventh edition, 64mo, roan, gilt edges, 1*s*.; or in cloth case, 1*s*. 6*d*.

This work is printed in a pearl type, and is so small, measuring only 2½ in. by 1¾ in. by ¼ in. thick, that it may be easily carried in the waistcoat pocket.

"It is certainly an extremely rare thing for a reviewer to be called upon to notice a volume measuring but 2½ in. by 1¾ in., yet these dimensions faithfully represent the size of the handy little book before us. The volume—which contains 118 printed pages, besides a few blank pages for memoranda—is, in fact, a true pocket-book, adapted for being carried in the waistcoat pocket, and containing a far greater amount and variety of information than most people would imagine could be compressed into so small a space. . . . . The little volume has been compiled with considerable care and judgment, and we can cordially recommend it to our readers as a useful little pocket companion."—*Engineering.*

A Practical Treatise on Natural and Artificial Concrete, its Varieties and Constructive Adaptations. By HENRY REID, Author of the 'Science and Art of the Manufacture of Portland Cement.' New Edition, *with* 59 *woodcuts and* 5 *plates*, 8vo, cloth, 15*s*.

Hydrodynamics: Treatise relative to the Testing of Water-Wheels and Machinery, with various other matters pertaining to Hydrodynamics. By JAMES EMERSON. *With numerous illustrations*, 360 pp. Third edition, crown 8vo, cloth, 4*s*. 6*d*.

Electricity as a Motive Power. By Count TH. DU MONCEL, Membre de l'Institut de France, and FRANK GERALDY, Ingénieur des Ponts et Chaussées. Translated and Edited, with Additions, by C. J. WHARTON, Assoc. Soc. Tel. Eng. and Elec. *With* 113 *engravings and diagrams*, crown 8vo, cloth, 7*s*. 6*d*.

Hints on Architectural Draughtsmanship. By G. W. TUXFORD HALLATT. Fcap. 8vo, cloth, 1*s*. 6*d*.

Treatise on Valve-Gears, with special consideration of the Link-Motions of Locomotive Engines. By Dr. GUSTAV ZEUNER, Professor of Applied Mechanics at the Confederated Polytechnikum of Zurich. Translated from the Fourth German Edition, by Professor J. F. KLEIN, Lehigh University, Bethlehem, Pa. *Illustrated*, 8vo, cloth, 12*s*. 6*d*.

The French-Polisher's Manual. By a French-Polisher; containing Timber Staining, Washing, Matching, Improving, Painting, Imitations, Directions for Staining, Sizing, Embodying, Smoothing, Spirit Varnishing, French-Polishing, Directions for Re-polishing. Third edition, royal 32mo, sewed, 6*d*.

Hops, their Cultivation, Commerce, and Uses in various Countries. By P. L. SIMMONDS. Crown 8vo, cloth, 4*s*. 6*d*.

A Practical Treatise on the Manufacture and Distribution of Coal Gas. By WILLIAM RICHARDS. Demy 4to, with *numerous wood engravings and* 29 *plates*, cloth, 28*s*.

SYNOPSIS OF CONTENTS:

Introduction — History of Gas Lighting — Chemistry of Gas Manufacture, by Lewis Thompson, Esq., M.R.C.S.—Coal, with Analyses, by J. Paterson, Lewis Thompson, and G. R. Hislop, Esqrs.—Retorts, Iron and Clay—Retort Setting—Hydraulic Main—Condensers — Exhausters — Washers and Scrubbers — Purifiers — Purification — History of Gas Holder — Tanks, Brick and Stone, Composite, Concrete, Cast-iron, Compound Annular Wrought-iron — Specifications — Gas Holders — Station Meter — Governor — Distribution—Mains—Gas Mathematics, or Formulæ for the Distribution of Gas, by Lewis Thompson, Esq.—Services—Consumers' Meters—Regulators—Burners—Fittings—Photometer—Carburization of Gas—Air Gas and Water Gas—Composition of Coal Gas, by Lewis Thompson, Esq.—Analyses of Gas—Influence of Atmospheric Pressure and Temperature on Gas—Residual Products—Appendix—Description of Retort Settings, Buildings, etc., etc.

Practical Geometry, Perspective, and Engineering Drawing; a Course of Descriptive Geometry adapted to the Requirements of the Engineering Draughtsman, including the determination of cast shadows and Isometric Projection, each chapter being followed by numerous examples; to which are added rules for Shading, Shade-lining, etc., together with practical instructions as to the Lining, Colouring, Printing, and general treatment of Engineering Drawings, with a chapter on drawing Instruments. By GEORGE S. CLARKE, Capt. R.E. Second edition, *with* 21 *plates*. 2 vols., cloth, 10*s*. 6*d*.

The Elements of Graphic Statics. By Professor KARL VON OTT, translated from the German by G. S. CLARKE, Capt. R.E., Instructor in Mechanical Drawing, Royal Indian Engineering College. *With* 93 *illustrations*, crown 8vo, cloth, 5*s*.

The Principles of Graphic Statics. By GEORGE SYDENHAM CLARKE, Capt. Royal Engineers. *With* 112 *illustrations*. 4to, cloth, 12*s*. 6*d*.

Dynamo-Electric Machinery: A Manual for Students of Electro-technics. By SILVANUS P. THOMPSON, B.A., D.Sc., Professor of Experimental Physics in University College, Bristol, etc., etc. Second edition, *illustrated*, 8vo, cloth, 12*s*. 6*d*.

The New Formula for Mean Velocity of Discharge of Rivers and Canals. By W. R. KUTTER. Translated from articles in the 'Cultur-Ingénieur,' by LOWIS D'A. JACKSON, Assoc. Inst. C.E. 8vo, cloth, 12*s.* 6*d.*

Practical Hydraulics; a Series of Rules and Tables for the use of Engineers, etc., etc. By THOMAS BOX. Fifth edition, *numerous plates*, post 8vo, cloth, 5*s.*

A Practical Treatise on the Construction of Horizontal and Vertical Waterwheels, specially designed for the use of operative mechanics. By WILLIAM CULLEN, Millwright and Engineer. *With* 11 *plates.* Second edition, revised and enlarged, small 4to, cloth, 12*s.* 6*d.*

Tin: Describing the Chief Methods of Mining, Dressing and Smelting it abroad; with Notes upon Arsenic, Bismuth and Wolfram. By ARTHUR G. CHARLETON, Mem. American Inst. of Mining Engineers. *With plates*, 8vo, cloth, 12*s.* 6*d.*

Perspective, Explained and Illustrated. By G. S. CLARKE, Capt. R.E. *With illustrations*, 8vo, cloth, 3*s.* 6*d.*

The Essential Elements of Practical Mechanics; based on the Principle of Work, designed for Engineering Students. By OLIVER BYRNE, formerly Professor of Mathematics, College for Civil Engineers. Third edition, *with* 148 *wood engravings*, post 8vo, cloth, 7*s.* 6*d.*

CONTENTS:

The Practical Millwright and Engineer's Ready Reckoner; or Tables for finding the diameter and power of cog-wheels, diameter, weight, and power of shafts, diameter and strength of bolts, etc. By THOMAS DIXON. Fourth edition, 12mo, cloth, 3*s.*

Breweries and Maltings: their Arrangement, Construction, Machinery, and Plant. By G. SCAMELL, F.R.I.B.A. Second edition, revised, enlarged, and partly rewritten. By F. COLYER, M.I.C.E., M.I.M.E. *With* 20 *plates*, 8vo, cloth, 18*s.*

A Practical Treatise on the Manufacture of Starch, Glucose, Starch-Sugar, and Dextrine, based on the German of L. Von Wagner, Professor in the Royal Technical School, Buda Pesth, and other authorities. By JULIUS FRANKEL; edited by ROBERT HUTTER, proprietor of the Philadelphia Starch Works. *With* 58 *illustrations*, 344 pp., 8vo, cloth, 18*s.*

A Practical Treatise on Mill-gearing, Wheels, Shafts, Riggers, etc.; for the use of Engineers. By THOMAS BOX. Third edition, *with* 11 *plates.* Crown 8vo, cloth, 7*s.* 6*d.*

Mining Machinery: a Descriptive Treatise on the Machinery, Tools, and other Appliances used in Mining. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Mem. of the Society of Engineers. Royal 4to, uniform with the Author's Treatise on Coal Mining, containing 182 *plates*, accurately drawn to scale, with descriptive text, in 2 vols., cloth, 3*l.* 12*s.*

CONTENTS:

Machinery for Prospecting, Excavating, Hauling, and Hoisting—Ventilation—Pumping—Treatment of Mineral Products, including Gold and Silver, Copper, Tin, and Lead, Iron Coal, Sulphur, China Clay, Brick Earth, etc.

Tables for Setting out Curves for Railways, Canals, Roads, etc., varying from a radius of five chains to three miles. By A. KENNEDY and R. W. HACKWOOD. *Illustrated*, 32mo, cloth, 2*s.* 6*d.*

The Science and Art of the Manufacture of Portland Cement, with observations on some of its constructive applications. *With* 66 *illustrations.* By HENRY REID, C.E., Author of 'A Practical Treatise on Concrete,' etc., etc. 8vo, cloth, 18*s.*

The Draughtsman's Handbook of Plan and Map Drawing; including instructions for the preparation of Engineering, Architectural, and Mechanical Drawings. *With numerous illustrations in the text, and* 33 *plates* (15 *printed in colours*). By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. 4to, cloth, 9*s.*

CONTENTS:

The Drawing Office and its Furnishings—Geometrical Problems—Lines, Dots, and their Combinations—Colours, Shading, Lettering, Bordering, and North Points—Scales—Plotting—Civil Engineers' and Surveyors' Plans—Map Drawing—Mechanical and Architectural Drawing—Copying and Reducing Trigonometrical Formulæ, etc., etc.

The Boiler-maker's and Iron Ship-builder's Companion, comprising a series of original and carefully calculated tables, of the utmost utility to persons interested in the iron trades. By JAMES FODEN, author of 'Mechanical Tables,' etc. Second edition revised, *with illustrations*, crown 8vo, cloth, 5*s.*

Rock Blasting: a Practical Treatise on the means employed in Blasting Rocks for Industrial Purposes. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. *With* 56 *illustrations and* 12 *plates*, 8vo, cloth, 10*s.* 6*d.*

Painting and Painters' Manual: a Book of Facts for Painters and those who Use or Deal in Paint Materials. By C. L. CONDIT and J. SCHELLER. *Illustrated*, 8vo, cloth, 10*s.* 6*d.*

A Treatise on Ropemaking as practised in public and private Rope-yards, with a Description of the Manufacture, Rules, Tables of Weights, etc., adapted to the Trade, Shipping, Mining, Railways, Builders, etc. By R. CHAPMAN, formerly foreman to Messrs. Huddart and Co., Limehouse, and late Master Ropemaker to H.M. Dockyard, Deptford. Second edition, 12mo, cloth, 3*s.*

Laxton's Builders' and Contractors' Tables; for the use of Engineers, Architects, Surveyors, Builders, Land Agents, and others. Bricklayer, containing 22 tables, with nearly 30,000 calculations. 4to, cloth, 5*s.*

Laxton's Builders' and Contractors' Tables. Excavator, Earth, Land, Water, and Gas, containing 53 tables, with nearly 24,000 calculations. 4to, cloth, 5*s.*

Sanitary Engineering: a Guide to the Construction of Works of Sewerage and House Drainage, with Tables for facilitating the calculations of the Engineer. By BALDWIN LATHAM, C.E., M. Inst. C.E., F.G.S., F.M.S., Past-President of the Society of Engineers. Second edition, *with numerous plates and woodcuts*, 8vo, cloth, 1*l.* 10*s.*

Screw Cutting Tables for Engineers and Machinists, giving the values of the different trains of Wheels required to produce Screws of any pitch, calculated by Lord Lindsay, M.P., F.R.S., F.R.A.S., etc. Cloth, oblong, 2*s.*

Screw Cutting Tables, for the use of Mechanical Engineers, showing the proper arrangement of Wheels for cutting the Threads of Screws of any required pitch, with a Table for making the Universal Gas-pipe Threads and Taps. By W. A. MARTIN, Engineer. Second edition, oblong, cloth, 1*s.*, or sewed, 6*d.*

A Treatise on a Practical Method of Designing Slide-Valve Gears by Simple Geometrical Construction, based upon the principles enunciated in Euclid's Elements, and comprising the various forms of Plain Slide-Valve and Expansion Gearing; together with Stephenson's, Gooch's, and Allan's Link-Motions, as applied either to reversing or to variable expansion combinations. By EDWARD J. COWLING WELCH, Memb. Inst. Mechanical Engineers. Crown 8vo, cloth, 6*s.*

Cleaning and Scouring: a Manual for Dyers, Laundresses, and for Domestic Use. By S. CHRISTOPHER. 18mo, sewed, 6*d.*

A Handbook of House Sanitation; for the use of all persons seeking a Healthy Home. A reprint of those portions of Mr. Bailey-Denton's Lectures on Sanitary Engineering, given before the School of Military Engineering, which related to the "Dwelling," enlarged and revised by his Son, E. F. BAILEY-DENTON, C.E., B.A. *With* 140 *illustrations*, 8vo, cloth, 8*s.* 6*d*

A Glossary of Terms used in Coal Mining. By WILLIAM STUKELEY GRESLEY, Assoc. Mem. Inst. C.E., F.G.S., Member of the North of England Institute of Mining Engineers. *Illustrated with numerous woodcuts and diagrams*, crown 8vo, cloth, 5*s*.

A Pocket-Book for Boiler Makers and Steam Users, comprising a variety of useful information for Employer and Workman, Government Inspectors, Board of Trade Surveyors, Engineers in charge of Works and Slips, Foremen of Manufactories, and the general Steam-using Public. By MAURICE JOHN SEXTON. Second edition, royal 32mo, roan, gilt edges, 5*s*.

Electrolysis: a Practical Treatise on Nickeling, Coppering, Gilding, Silvering, the Refining of Metals, and the treatment of Ores by means of Electricity. By HIPPOLYTE FONTAINE, translated from the French by J. A. BERLY, C.E., Assoc. S.T.E. *With engravings.* 8vo, cloth, 9*s*.

A Practical Treatise on the Steam Engine, containing Plans and Arrangements of Details for Fixed Steam Engines, with Essays on the Principles involved in Design and Construction. By ARTHUR RIGG, Engineer, Member of the Society of Engineers and of the Royal Institution of Great Britain. Demy 4to, *copiously illustrated with woodcuts and* 96 *plates*, in one Volume, half-bound morocco, 2*l*. 2*s*.; or cheaper edition, cloth, 25*s*.

This work is not, in any sense, an elementary treatise, or history of the steam engine, but is intended to describe examples of Fixed Steam Engines without entering into the wide domain of locomotive or marine practice. To this end illustrations will be given of the most recent arrangements of Horizontal, Vertical, Beam, Pumping, Winding, Portable, Semi-portable, Corliss, Allen, Compound, and other similar Engines, by the most eminent Firms in Great Britain and America. The laws relating to the action and precautions to be observed in the construction of the various details, such as Cylinders, Pistons, Piston-rods, Connecting-rods, Cross-heads, Motion-blocks, Eccentrics, Simple, Expansion, Balanced, and Equilibrium Slide-valves, and Valve-gearing will be minutely dealt with. In this connection will be found articles upon the Velocity of Reciprocating Parts and the Mode of Applying the Indicator, Heat and Expansion of Steam Governors, and the like. It is the writer's desire to draw illustrations from every possible source, and give only those rules that present practice deems correct.

Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to 10,000. Post 8vo, cloth, 6*s*.

Camus (M.) Treatise on the Teeth of Wheels, demonstrating the best forms which can be given to them for the purposes of Machinery, such as Mill-work and Clock-work, and the art of finding their numbers. Translated from the French, with details of the present practice of Millwrights, Engine Makers, and other Machinists, by ISAAC HAWKINS. Third edition, *with* 18 *plates*, 8vo, cloth, 5*s*.

A Practical Treatise on the Science of Land and Engineering Surveying, Levelling, Estimating Quantities, etc., with a general description of the several Instruments required for Surveying, Levelling, Plotting, etc. By H. S. MERRETT. Fourth edition, revised by G. W. USILL, Assoc. Mem. Inst. C.E. 41 *plates, with illustrations and tables*, royal 8vo, cloth, 12*s*. 6*d*.

PRINCIPAL CONTENTS:

Part 1. Introduction and the Principles of Geometry. Part 2. Land Surveying; comprising General Observations—The Chain—Offsets Surveying by the Chain only—Surveying Hilly Ground—To Survey an Estate or Parish by the Chain only—Surveying with the Theodolite—Mining and Town Surveying—Railroad Surveying—Mapping—Division and Laying out of Land—Observations on Enclosures—Plane Trigonometry. Part 3. Levelling—Simple and Compound Levelling—The Level Book—Parliamentary Plan and Section—Levelling with a Theodolite—Gradients—Wooden Curves—To Lay out a Railway Curve—Setting out Widths. Part 4. Calculating Quantities generally for Estimates—Cuttings and Embankments—Tunnels—Brickwork—Ironwork—Timber Measuring. Part 5. Description and Use of Instruments in Surveying and Plotting—The Improved Dumpy Level—Troughton's Level—The Prismatic Compass—Proportional Compass—Box Sextant—Vernier—Pantagraph—Merrett's Improved Quadrant—Improved Computation Scale—The Diagonal Scale—Straight Edge and Sector. Part 6. Logarithms of Numbers—Logarithmic Sines and Co-Sines, Tangents and Co-Tangents—Natural Sines and Co-Sines—Tables for Earthwork, for Setting out Curves, and for various Calculations, etc., etc., etc.

Saws: the History, Development, Action, Classification, and Comparison of Saws of all kinds. By ROBERT GRIMSHAW. *With* 220 *illustrations*, 4to, cloth, 12*s*. 6*d*.

A Supplement to the above; containing additional practical matter, more especially relating to the forms of Saw Teeth for special material and conditions, and to the behaviour of Saws under particular conditions. *With* 120 *illustrations*, cloth, 9*s*.

A Guide for the Electric Testing of Telegraph Cables. By Capt. V. HOSKICÆR, Royal Danish Engineers. *With illustrations*, second edition, crown 8vo, cloth, 4*s*. 6*d*.

Laying and Repairing Electric Telegraph Cables. By Capt. V. HOSKICÆR, Royal Danish Engineers. Crown 8vo, cloth, 3*s*. 6*d*.

A Pocket-Book of Practical Rules for the Proportions of Modern Engines and Boilers for Land and Marine purposes. By N. P. BURGH. Seventh edition, royal 32mo, roan, 4*s*. 6*d*.

The Assayer's Manual: an Abridged Treatise on the Docimastic Examination of Ores and Furnace and other Artificial Products. By BRUNO KERL. Translated by W. T. BRANNT. *With* 65 *illustrations*, 8vo, cloth, 12*s*. 6*d*.

The Steam Engine considered as a Heat Engine: a Treatise on the Theory of the Steam Engine, illustrated by Diagrams, Tables, and Examples from Practice. By JAS. H. COTTERILL, M.A., F.R.S., Professor of Applied Mechanics in the Royal Naval College. 8vo, cloth, 12*s*. 6*d*.

Electricity: its Theory, Sources, and Applications. By J. T. SPRAGUE, M.S.T.E. Second edition, revised and enlarged, *with numerous illustrations*, crown 8vo, cloth, 15*s*.

The Practice of Hand Turning in Wood, Ivory, Shell, etc., with Instructions for Turning such Work in Metal as may be required in the Practice of Turning in Wood, Ivory, etc.; also an Appendix on Ornamental Turning. (A book for beginners.) By FRANCIS CAMPIN. Third edition, *with wood engravings*, crown 8vo, cloth, 6*s*.

CONTENTS:

On Lathes—Turning Tools—Turning Wood—Drilling—Screw Cutting—Miscellaneous Apparatus and Processes—Turning Particular Forms—Staining—Polishing—Spinning Metals—Materials—Ornamental Turning, etc.

Health and Comfort in House Building, or Ventilation with Warm Air by Self-Acting Suction Power, with Review of the mode of Calculating the Draught in Hot-Air Flues, and with some actual Experiments. By J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. Second edition, with Supplement, *with plates*, demy 8vo, cloth, 7*s*. 6*d*.

Treatise on Watchwork, Past and Present. By the Rev. H. L. NELTHROPP, M.A., F.S.A. *With* 32 *illustrations*, crown 8vo, cloth, 6*s*. 6*d*.

CONTENTS:

Definitions of Words and Terms used in Watchwork—Tools—Time—Historical Summary—On Calculations of the Numbers for Wheels and Pinions; their Proportional Sizes, Trains, etc.—Of Dial Wheels, or Motion Work—Length of Time of Going without Winding up—The Verge—The Horizontal—The Duplex—The Lever—The Chronometer—Repeating Watches—Keyless Watches—The Pendulum, or Spiral Spring—Compensation—Jewelling of Pivot Holes—Clerkenwell—Fallacies of the Trade—Incapacity of Workmen—How to Choose and Use a Watch, etc.

Notes in Mechanical Engineering. Compiled principally for the use of the Students attending the Classes on this subject at the City of London College. By HENRY ADAMS, Mem. Inst. M.E., Mem. Inst. C.E., Mem. Soc. of Engineers. Crown 8vo, cloth, 2*s*. 6*d*.

Algebra Self-Taught. By W. P. HIGGS, M.A., D.Sc., LL.D., Assoc. Inst. C.E., Author of 'A Handbook of the Differential Calculus,' etc. Second edition, crown 8vo, cloth, 2*s*. 6*d*.

CONTENTS:

Symbols and the Signs of Operation—The Equation and the Unknown Quantity—Positive and Negative Quantities—Multiplication—Involution—Exponents—Negative Exponents—Roots, and the Use of Exponents as Logarithms—Logarithms—Tables of Logarithms and Proportionate Parts—Transformation of System of Logarithms—Common Uses of Common Logarithms—Compound Multiplication and the Binomial Theorem—Division, Fractions, and Ratio—Continued Proportion—The Series and the Summation of the Series—Limit of Series—Square and Cube Roots—Equations—List of Formulæ, etc.

Spons' Dictionary of Engineering, Civil, Mechanical, Military, and Naval; with technical terms in French, German, Italian, and Spanish, 3100 pp., and *nearly* 8000 *engravings*, in super-royal 8vo, in 8 divisions, 5*l*. 8*s*. Complete in 3 vols., cloth, 5*l*. 5*s*. Bound in a superior manner, half-morocco, top edge gilt, 3 vols., 6*l*. 12*s*.

Canoe and Boat Building: a complete Manual for Amateurs, containing plain and comprehensive directions for the construction of Canoes, Rowing and Sailing Boats, and Hunting Craft. By W. P. STEPHENS. *With numerous illustrations and 24 plates of Working Drawings.* Crown 8vo, cloth, 7*s.* 6*d.*

Cultural Industries for Queensland: Papers on the cultivation of useful Plants suited to the climate of Queensland, their value as Food, in the Arts, and in Medicine, and methods of obtaining their products. By L. A. BERNAYS, F.L.S., F.R.G.S. 8vo, half calf, 7*s.* 6*d.* The same, in cloth, 6*s.*

Proceedings of the National Conference of Electricians, Philadelphia, October 8th to 13th, 1884. 18mo, cloth, 3*s.*

Dynamo-Electricity, its Generation, Application, Transmission, Storage, and Measurement. By G. B. PRESCOTT. *With 545 illustrations.* 8vo, cloth, 1*l.* 1*s.*

Domestic Electricity for Amateurs. Translated from the French of E. HOSPITALIER, Editor of "L'Electricien," by C. J. WHARTON, Assoc. Soc. Tel. Eng. *Numerous illustrations.* Demy 8vo, cloth, 9*s.*

CONTENTS:

1. Production of the Electric Current—2. Electric Bells—3. Automatic Alarms—4. Domestic Telephones—5. Electric Clocks—6. Electric Lighters—7. Domestic Electric Lighting—8. Domestic Application of the Electric Light—9. Electric Motors—10. Electrical Locomotion—11. Electrotyping, Plating, and Gilding—12. Electric Recreations—13. Various applications—Workshop of the Electrician.

Wrinkles in Electric Lighting. By VINCENT STEPHEN. *With illustrations.* 18mo, cloth, 2*s.* 6*d.*

CONTENTS:

1. The Electric Current and its production by Chemical means—2. Production of Electric Currents by Mechanical means—3. Dynamo-Electric Machines—4. Electric Lamps—5. Lead—6. Ship Lighting.

The Practical Flax Spinner; being a Description of the Growth, Manipulation, and Spinning of Flax and Tow. By LESLIE C. MARSHALL, of Belfast. *With illustrations.* 8vo, cloth, 15*s.*

Foundations and Foundation Walls for all classes of Buildings, Pile Driving, Building Stones and Bricks, Pier and Wall construction, Mortars, Limes, Cements, Concretes, Stuccos, &c. 64 *illustrations.* By G. T. POWELL and F. BAUMAN. 8vo, cloth, 10*s.* 6*d.*

The British Jugernath. Free Trade! Fair Trade!! Reciprocity!!! and Retaliation!!!! By G. L. M. 8vo, sewed. 6*d.*

Manual for Gas Engineering Students. By D. LEE. 18mo, cloth 1*s.*

Hydraulic Machinery, Past and Present. A Lecture delivered to the London and Suburban Railway Officials' Association. By H. ADAMS, Mem. Inst. C.E. *Folding plate.* 8vo, sewed, 1*s.*

Twenty Years with the Indicator. By THOMAS PRAY, Jun., C.E., M.E., Member of the American Society of Civil Engineers. 2 vols., royal 8vo, cloth, 12*s.* 6*d.*

Annual Statistical Report of the Secretary to the Members of the Iron and Steel Association on the Home and Foreign Iron and Steel Industries in 1884. Issued March 1885. 8vo, sewed, 5*s.*

Bad Drains, and How to Test them; with Notes on the Ventilation of Sewers, Drains, and Sanitary Fittings, and the Origin and Transmission of Zymotic Disease. By R. HARRIS REEVES. Crown 8vo, cloth, 3*s.* 6*d.*

Standard Practical Plumbing; being a complete Encyclopædia for Practical Plumbers and Guide for Architects, Builders, Gas Fitters, Hot-water Fitters, Ironmongers, Lead Burners, Sanitary Engineers, Zinc Workers, &c. *Illustrated by over* 2000 *engravings.* By P. J. DAVIES. Vol. 1, royal 8vo, cloth, 7*s.* 6*d.*

Pneumatic Transmission of Messages and Parcels between Paris and London, viâ Calais and Dover. By J. B. BERLIER, C.E. Small folio, sewed, 6*d.*

List of Tests (Reagents), arranged in alphabetical order, according to the names of the originators. Designed especially for the convenient reference of Chemists, Pharmacists, and Scientists. By HANS M. WILDER. Crown 8vo, cloth, 4*s.* 6*d.*

Ten Years' Experience in Works of Intermittent Downward Filtration. By J. BAILEY DENTON, Mem. Inst. C.E. Second edition, with additions. Royal 8vo, sewed, 4*s.*

A Treatise on the Manufacture of Soap and Candles, Lubricants and Glycerin. By W. LANT CARPENTER, B.A., B.Sc. (late of Messrs. C. Thomas and Brothers, Bristol). *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

The Stability of Ships explained simply, and calculated by a new Graphic method. By J. C. SPENCE, M.I.N.A. 4to, sewed, 3*s.* 6*d.*

Steam Making, or Boiler Practice. By CHARLES A. SMITH, C.E. 8vo, cloth, 10*s.* 6*d.*

CONTENTS:

1. The Nature of Heat and the Properties of Steam—2. Combustion.—3. Externally Fired Stationary Boilers—4. Internally Fired Stationary Boilers—5. Internally Fired Portable Locomotive and Marine Boilers—6. Design, Construction, and Strength of Boilers—7. Proportions of Heating Surface, Economic Evaporation, Explosions—8. Miscellaneous Boilers, Choice of Boiler Fittings and Appurtenances.

The Fireman's Guide; a Handbook on the Care of Boilers. By TEKNOLOG, föreningen T. I. Stockholm. Translated from the third edition, and revised by KARL P. DAHLSTROM, M.E. Second edition. Fcap. 8vo, cloth, 2*s.*

A Treatise on Modern Steam Engines and Boilers, including Land Locomotive, and Marine Engines and Boilers, for the use of Students. By FREDERICK COLYER, M. Inst. C.E., Mem. Inst. M.E. *With* 36 *plates.* 4to, cloth, 25*s.*

CONTENTS:

1. Introduction—2. Original Engines—3. Boilers—4. High-Pressure Beam Engines—5. Cornish Beam Engines—6. Horizontal Engines—7. Oscillating Engines—8. Vertical High-Pressure Engines—9. Special Engines—10. Portable Engines—11. Locomotive Engines—12. Marine Engines.

Steam Engine Management; a Treatise on the Working and Management of Steam Boilers. By F. COLYER, M. Inst. C.E., Mem. Inst. M.E. 18mo, cloth, 2*s.*

Land Surveying on the Meridian and Perpendicular System. By WILLIAM PENMAN, C.E. 8vo, cloth, 8*s.* 6*d.*

The Topographer, his Instruments and Methods, designed for the use of Students, Amateur Photographers, Surveyors, Engineers, and all persons interested in the location and construction of works based upon Topography. *Illustrated with numerous plates, maps, and engravings.* By LEWIS M. HAUPT, A.M. 8vo, cloth, 18*s.*

A Text-Book of Tanning, embracing the Preparation of all kinds of Leather. By HARRY R. PROCTOR, F.C.S., of Low Lights Tanneries. *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

92